W. B. No. 143.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

Bulletin E.

FLOODS

OF THE

MISSISSIPPI RIVER.

PREPARED UNDER DIRECTION OF

WILLIS L. MOORE,

CHIEF OF WEATHER BUREAU.

BY

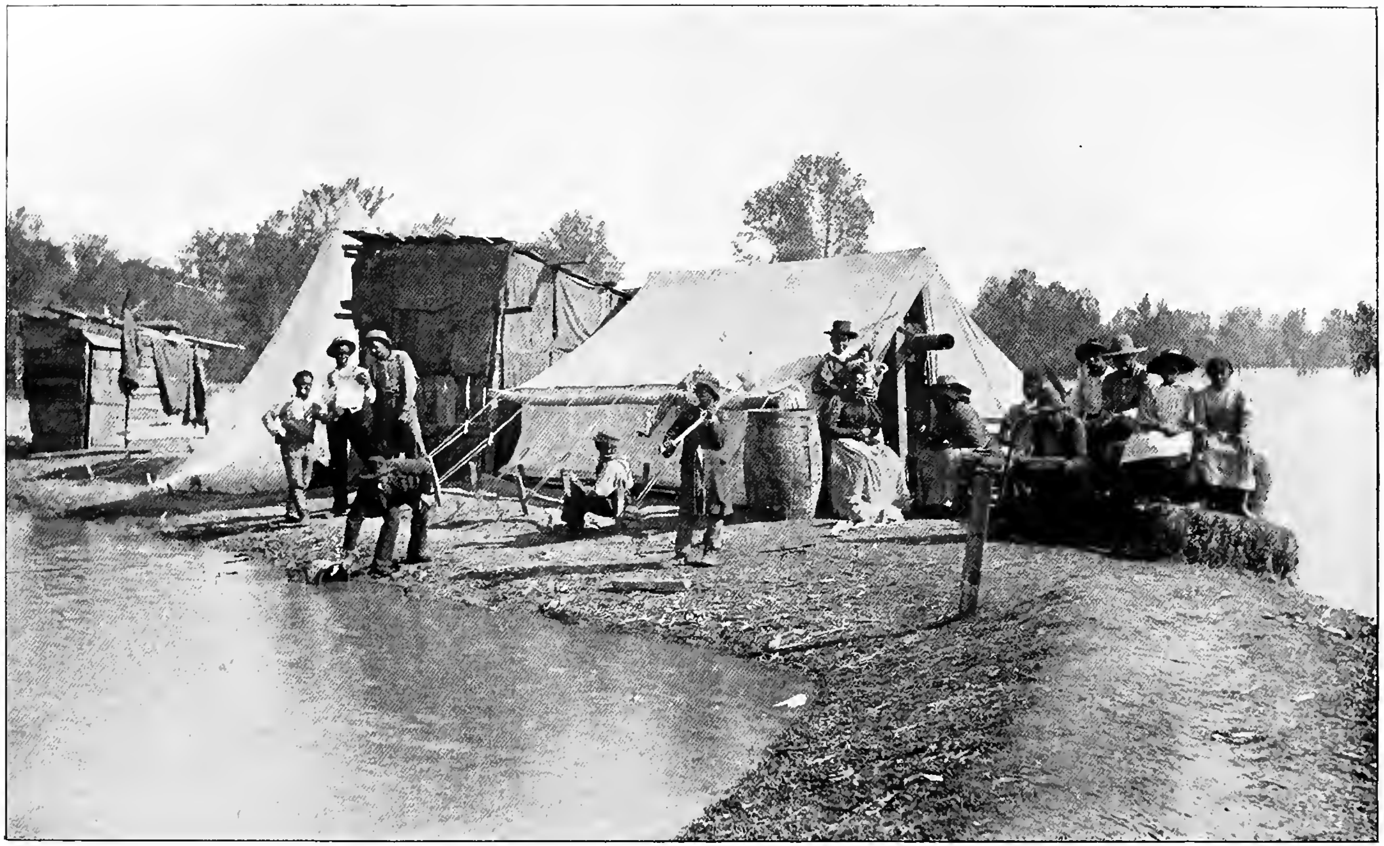
PARK MORRILL,

FORECAST OFFICIAL, IN CHARGE OF RIVER AND FLOOD SERVICE.

WASHINGTON:

WEATHER BUREAU.

1897.



Flood Refugees upon a Mississippi Levee.

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U. S. Department of Agriculture, Weather Bureau,
Washington, D. C., October 1, 1897.

Sir: I have the honor to transmit herewith a paper upon the floods of the Mississippi river, and especially the notable flood of last spring, which has been prepared under my personal supervision by Mr. Park Morrill, Forecast Official, in charge of the River and Flood Service, and to recommend its publication as a bulletin of the Weather Bureau. The effort has been made to briefly cover the entire regimen of the river, both in its normal condition and in flood. The physical characteristics of the Mississippi basin and river have been reviewed, and the best data available as to area of watersheds, dimensions and slope of the main stream and its tributaries, are given, largely in tabular form, convenient for reference.

The records of the Weather Bureau have been used to determine the normal precipitation for each month and for the year. The charts of normal precipitation which accompany the paper are thought to be the most accurate yet prepared for the region covered, which is practically all that portion of the United States lying east of the Great Divide. The resultant downfall of water over the various subdivisions of the grand basin has been computed, and is presented in the tables. Normal river stages at various stations have been computed, and are here published for the first time, so far as known. The chart of normal hydrographs drawn from these data is instructive, showing at a glance the annual rise and fall of the Mississippi and its chief feeders. Other facts as to extreme stages of the rivers, the volume of discharge, and similar matters, have been collated from many sources, and are here presented in convenient form.

Having treated of the normal conditions of water supply and drainage throughout the basin, the subject of floods is next considered at some length. The floods occurring during the past twenty-six years are made the chief subject of study, inasmuch as only during that time are complete and reliable gauge readings available. Six notable flood years are embraced in this period, and for these six floods hydrographs have been drawn for several typical stations. The downfall of water from which each flood arose has been computed, and the results are given in tabular form. Corresponding charts of actual precipitation and of the departure from the normal precipitation have also been constructed for each flood, and accompany the report. Through our own observers, and from the investigations of the engineer officers in charge of levee work, a map of the region inundated this year has been prepared, and forms an interesting accompaniment to the paper.

Respectfully,

Willis L. Moore,
Chief of Weather Bureau.

Hon. James Wilson,
Secretary of Agriculture.

FLOODS OF THE MISSISSIPPI RIVER.

SECTION I.

THE RIVER AND BASIN.

Introductory.—Sources of information.—The drainage basin.—Ohio basin.—Upper Mississippi basin.—Missouri basin.—Arkansas basin.—Red basin.—Central valley.—Lower Mississippi river.

IT is proposed in the present paper to consider briefly the chief characteristics of the Mississippi river, and of the basin that is drained by it and its numerous tributaries. In view of the great importance of this river system to a large part of the inhabitants of the United States, of whom, according to the census of 1890, twenty-seven and a half millions, in round numbers, dwell in its basin, it is thought that such a paper will be of interest and value. This is further assured because of the great loss of property and danger to life sometimes incurred through the floods of the Lower Mississippi, which may be in part avoided by timely prevision. It is proposed to bring together from various sources the chief facts as to the physical characteristics of the catchment basin. To this will succeed data as to its precipitation and drainage under normal conditions, better information with respect to which is now obtainable than has been anywhere brought together in a convenient form. Lastly, the floods of the Lower Mississippi will be considered, and especially that of the present year. The subject naturally separates itself into these divisions, and will be treated in the above order.

SOURCES OF INFORMATION.

1. *Work of Delta Survey, River Commissions, and Weather Bureau.*—The first thorough and systematic investigation of the regimen of the Mississippi River was made by the Delta Survey, organized by act of Congress in 1850. The final report of the survey and investigations instituted, was made in 1861 by Capt. A. A. Humphreys and Lieut. Henry L. Abbot. Their report has remained to the present time the main authority as to the physical features of the river. By an act of Congress, passed in 1871, the Secretary of War was directed to establish gauges at various points on the Mississippi and its principal tributaries, and daily observations of these gauges have been made ever since under the direction of the Engineer Corps. In 1879 the Mississippi River Commission was created, and has accurately surveyed the course of the Mississippi, and determined its slope by precise levels. Additional gauges have been established, so that its daily stage is now recorded at intervals of about 50 miles. The

Missouri River Commission was organized in 1884, and has done similar work upon the Missouri. The Weather Bureau began in 1873 to collect the daily readings of river gauges by telegraph, and to publish them for the benefit of river commerce. Besides the presentation of the current stages of rivers, it early inaugurated a system of flood warnings, for which the telegraphic collection of river stages and rainfall gave especial opportunity. In the prosecution of this work many gauges have been established, largely upon the smaller tributaries, which were not embraced in the work of other departments of the Government. As a result of these various labors, there has been accumulated a large quantity of observations and other data, relating to the Mississippi and its tributary rivers. Moreover, since the creation of the Weather Bureau in 1870, the precipitation, as well as other meteorological subjects, has been carefully investigated for the whole country, and a knowledge of the precipitation over its basin, as well as of the regimen of the river itself, in order to fully understand the latter, is clearly necessary.

THE DRAINAGE BASIN.

2. *Comparison of the Mississippi with other river systems.*—Through a faulty nomenclature, the Mississippi river is only 2,485 miles in length. In point of fact the Missouri is the proper prolongation of the main river, the Upper Mississippi being in reality one of its less important tributaries. From the mouth of the Mississippi to the sources of the Missouri, the river distance is about 4,190 miles, constituting possibly the longest waterway in the world. Its only rivals in length are the Nile and the Amazon, the precise length of neither of which is known, but is estimated for each at about 4,000 miles. The region drained by the Mississippi embraces about 1,240,050 square miles, or 41 per cent of the total area of the United States, exclusive of Alaska. In the extent of its drainage area the Mississippi is probably surpassed only by the Amazon, and is about equaled by the Obi. On an average there is carried to the sea each year by the Mississippi 159 cubic miles of water, and in this it is exceeded by the Amazon and probably the Congo and Yangtse Kiang. At certain seasons steamers can ascend to the Great Falls of the Missouri, a distance of 3,950 miles from the gulf of Mexico. The navigable waters of the Mississippi and its tributaries are estimated at 15,000 miles.

3. *Extent of the basin.*—The catchment basin of the Mississippi covers 56 degrees of longitude and 21 degrees of latitude, and discloses a great diversity of climate. The sources of its most southerly tributary from the west, the Red, are on the confines of the arid Staked Plains; the western tributaries of the Arkansas are fed by the melting snows of the loftiest of the Rocky mountains; the western streams of the Missouri basin rise in the canyons of Montana and Wyoming, and its northern ones in blizzard-swept Assiniboia; the headwaters of the Upper Mississippi lie among the pine woods of Minnesota; the whole western slope of the Alleghanies is drained by the Ohio, whose most northerly tributary extends into New York, and its most southerly into Alabama. The western tributaries of the Mississippi, crossing the treeless levels of the western plains, and the eastern branches, from the wooded slopes of the Alleghanies, all seek the alluvial bed that stretches from Cairo to the Delta. From the mouth of the Ohio southward, the great river, now clothed in all its majesty, flows for nearly 1,100 miles through a level and swampy land to the Delta. Within the limits of the basin are found variations of

temperature from almost arctic cold to semitropic heat; and of rainfall from desert dryness to reeking moisture.

4. *Subdivisions of the Mississippi drainage basin.*—The drainage basin of the Mississippi embraces six great natural divisions, the basins of the Ohio, Upper Mississippi, Missouri, Arkansas, and Red rivers, together with a comparatively narrow strip of country which extends along the Mississippi river from the mouth of the Missouri to the Gulf, and is drained by many small streams. The last section may be conveniently designated as the Central Valley, and terminates in the Delta, lying south of the Red river. The boundaries and location of these subdivisions are shown by the shaded areas of Plate I, and their extent is given in the following table:

TABLE I.—*Grand divisions of the Mississippi basin.*

Designation.	Area in square miles.	Ratio to whole basin.
Ohio basin	201, 700	0. 16
Upper Mississippi basin	165, 900	0. 13
Missouri basin	527, 150	0. 43
Arkansas basin	186, 300	0. 15
Red basin	90, 000	0. 07
Central Valley	69, 000	0. 06
Total	1, 240, 050	1. 00

The secondary basins are seen to be of very unequal extent, that of the Missouri being much the greatest, and the Central Valley the smallest; they also differ widely in their geographical and meteorological features, and it will be well to consider them a little more in detail.

OHIO BASIN.

5. *Character of the basin.*—The drainage basin of the Ohio is second in size of the six component divisions of the Mississippi basin, and is the most densely populated. Its northern boundary is along the slightly elevated plateau south of the Great Lakes; along lake Erie it runs nowhere more than 50 miles from the lake shore, and farther west it approaches as closely to lake Michigan. The eastern and southern boundary lies along the crests of the Alleghanies for 700 or 800 miles. Down the western slopes of these mountains, through a rugged and heavily timbered country, flow the streams that form the Tennessee, Cumberland, Kentucky, Big Sandy, Great Kanawha, Little Kanawha, and Monongahela rivers. These streams have a steep slope, and are subject to great and sudden fluctuations in volume. The Alleghany drains northwestern Pennsylvania and southwestern New York; its tributaries also lie in a mountainous region, and its discharge shows the same variability. The northern tributaries, of which the Wabash is the largest, flow through a very different region; the ground, somewhat broken near the Ohio, becomes a gently rolling land farther north, and is now generally cleared of timber. Largely from this difference in surface features, results the fact that most of the freshets in the Ohio come out of its southern and eastern branches.

6. *The Ohio river.*—From its formation by the junction of the Alleghany and Monongahela to its mouth, the Ohio is 965 miles in length; its remote sources are

2,370 miles from the gulf of Mexico. Throughout its length it is interrupted by rapids only at the falls of the Ohio, near Louisville. As will appear later, the Ohio makes a greater annual contribution to the waters discharged by the Mississippi than any other tributary. Yet, in low water, it becomes a succession of long pools and ripples, only navigable by boats of the lightest draft. The width of the river in low water is about 1,000 feet in its upper reaches, and 2,500 near the mouth. The corresponding cross sections are, approximately, 5,000 and 50,000 square feet, which become in flood 50,000 and 150,000 square feet, respectively. The descent in the Ohio from Pittsburg to Cairo is 430 feet, or an average of 0.44 foot per mile for the entire length of the river.

7. *Smaller divisions of the Ohio basin.*—It will be useful hereafter, in investigating the downfall of water over a great basin, like that of the Ohio, to consider the smaller drainage areas of which it is composed. Each section will be designated by a letter, and the various sections are shown in different patterns in the shading on the map of the drainage basin, Plate I. The drainage areas of the smaller tributaries, entering the same portion of the river, are combined together. The various sections are clearly indicated on the map and require no detailed description. The areas of the various subdivisions of the Ohio basin are given in the following table:

TABLE II.—*Subdivisions of the Ohio basin.*

Designation.	Area in square miles.	Ratio to whole basin.
A	19, 050	0. 10
B	32, 300	0. 16
C	27, 300	0. 14
D	25, 000	0. 12
E	35, 150	0. 17
F	18, 600	0. 09
G	44, 300	0. 22
Total	201, 700	1. 00

UPPER MISSISSIPPI BASIN.

8. *The Upper Mississippi river.*—The Mississippi river above the mouth of the Missouri is designated as the Upper Mississippi, and, although bearing the name of the main stream, is in reality a tributary. It rises in lake Itasca, a sheet of clear water 7 miles long and from 1 to 3 miles wide. This lake lies in a swampy region, abounding in ponds and lakes, and covered with pine forest. The shallow stream, 10 or 12 feet in width, which leaves lake Itasca, meanders through woodland and grassy intervals, several times expanding into lakes. It leaves the last of these, Winnibigoshish lake, as a stream 60 feet in width. From this point to the falls of St. Anthony, the river follows a winding course, and contains several rapids. The falls of St. Anthony are the head of navigation, at a distance of 690 miles above the mouth of the Missouri, and 1,970 miles from the mouth of the Mississippi; from the extreme source of the river to the gulf of Mexico, the distance is about 2,485 miles. Below the falls of St. Anthony, the Upper Mississippi is a broad and placid stream, expanding 65 miles below the falls into lake Pepin, which is 2 to 3 miles wide and 27 miles long. The river is filled with innumerable wooded islands, which make its entire width about 1 mile. At a short distance back from the river rise bluffs, and between the bluffs and river are fertile

flats, especially at the mouths of the tributaries. The latter are numerous throughout its course, but mostly small, the last and largest being the Illinois. The navigable river is interrupted by rapids at two points; at Rock Island the stream descends 20 feet in a distance of 12 miles, over a succession of rocky steps, and at the Des Moines rapids, above Keokuk, there is a fall of 22 feet in 11 miles. The descent in the Upper Mississippi, from St. Anthonys falls to the mouth of the Missouri, is 407 feet, or an average of 0.59 foot per mile. The cross section of the river in flood, near its junction with the Missouri, is estimated at about 100,000 square feet.

9. *Character and extent of the basin.*—The drainage basin of the Upper Mississippi is fourth in size of the secondary basins, being exceeded by those of the Ohio and Arkansas, as well as that of the Missouri. Its eastern boundary approaches very closely to lake Michigan, in the vicinity of Chicago; farther north it recedes from the lake, passing through central Wisconsin and into upper Michigan. Turning westward it extends along the plateau some 50 miles south of lake Superior, and then crosses northern Minnesota. From the narrow divide, separating the headwaters of the Minnesota river and those of the Red River of the North, the boundary runs southeast to the mouth of the Missouri. This basin is relatively low and level, containing no mountains; its central and southern portions are prairie land. It lies on an average some 5 degrees farther north than the basin of the Ohio, and during the winter months its streams are ice-bound. The drainage area is subdivided into four sections after the manner followed in treating of the Ohio basin. These are shown on the drainage map, Plate I, and their areas are as follows:

TABLE III.—*Subdivisions of the Upper Mississippi basin.*

Designation.	Area in square miles.	Ratio to whole basin.
A	55, 950	0. 34
B	37, 350	0. 22
C	43, 450	0. 26
D	29, 150	0. 18
Total	165, 900	1. 00

MISSOURI BASIN.

10. *Extent and diversified character.*—The basin of the Missouri is the largest of the six divisions of the Mississippi basin, being two and one-half times as great as the next in size, that of the Ohio. As will appear hereafter, it is also the driest of the secondary basins and hence, notwithstanding its great extent, it is third in the volume of its annual drainage. From the sources of Marias river, in western Montana, to those of the Gasconade, in southern Missouri, it extends 1,350 miles in a southeast direction. Its northern edge reaches 75 miles beyond the northern boundary of the United States. Where the boundary line reenters the United States in western Montana, it turns southward, and runs at an elevation of from 6,000 to 14,000 feet in a southeasterly direction to central Colorado. The southern boundary extends from Colorado, across Kansas and Missouri, in an easterly direction, descending rapidly at first and then more slowly, until, at the mouth of the Missouri, the low-water surface is

only 400 feet above sea level. The variety of topographical features within this basin is unsurpassed. The mountainous western section, filled with spurs from the central ridge of the Rocky mountains, is of the wildest character. In its higher portions the snow remains long after it has vanished at lower levels, and on the loftier peaks is never absent. The rapid streams, which descend the mountain valleys, have cut deep canyons, with almost vertical sides of solid rock. From the base of the mountains, barren and treeless plains stretch eastward, with alkaline soil and water. These gradually change to more fertile prairies, sloping imperceptibly southeastward to the central valley of the Mississippi basin, and the rivers change in character to shallow, muddy streams with shifting beds of sand.

11. *The Missouri river.*—The Missouri river is formed by the junction of Jefferson, Madison, and Gallatin forks. These streams unite in a plain, surrounded by lofty peaks, and flow for some 60 or 70 miles through wild valleys and deep canyons, finally issuing into the barren foothills. About 35 miles above Benton, Mont., are located the Great Falls, where is the head of navigation. From this point the river is navigable in summer to its mouth, a distance of about 2,670 miles. From its extreme sources, the length of the river is about 2,910 miles, and the distance to the gulf of Mexico 4,190 miles. The first considerable tributary is the Yellowstone, which rises in many branches among the mountains to the south of the sources of the Missouri. At their junction the Yellowstone is of about the same size as the main stream. From this point the river assumes the character which it maintains to its mouth. The water is thick and muddy, from the washing away of the river banks, and this alluvial matter is borne onward to the gulf of Mexico, imparting the same turgid appearance to the Lower Mississippi. The current separates into many channels, forming numerous sandy islands, which are often covered with cottonwood trees. Below the confluence of the Yellowstone, the width of the river is nearly uniform to its mouth, ranging from one-third to half a mile when bank-full. Many tributaries add their water to the Missouri below the mouth of the Yellowstone, the more important being the Platte and the Kansas. All are much alike in character, and are broad and shallow streams, with sandy beds, and contain many sandbars. From the foot of the Great Falls to its mouth, the Missouri descends about 2,585 feet, or an average of 0.97 foot per mile. The cross section at the mouth is approximately 75,000 square feet in high water.

It is convenient to divide the Missouri basin into eight sections, as shown on the drainage map, Plate I, and their areas are given in the following table:

TABLE IV.—*Subdivisions of the Missouri basin.*

Designation.	Area in square miles.	Ratio to whole basin.
A	98,750	0.19
B	69,700	0.13
C	73,000	0.14
D	40,550	0.08
E	41,800	0.08
F	90,000	0.17
G	59,250	0.11
H	54,100	0.10
Total	527,150	1.00

The differences between the various sections of this basin in respect to climate, as well as in physical characteristics, are far greater than exist in the basins previously considered. The northwestern portion is one of the driest regions of the country, while, at the southeast extremity of the basin, there is a fair annual precipitation. The former region is also subject to extreme ranges of temperature.

ARKANSAS BASIN.

12. *Character of the basin.*—The basin of the Arkansas river bears a close resemblance to that of the Missouri in its variety of topography and its dryness. It holds the third place in point of size, but its annual drainage is the least with the exception of that of the Red river basin. In shape the basin is long and narrow, covering 14 degrees in longitude, with a width of 2 to 4 degrees of latitude. Its western boundary runs along the main ridge of the Rocky mountains in Colorado and New Mexico, and the western portion of the basin possesses the same wild and rugged character as the corresponding portion of the Missouri basin. Eastward from the mountains stretch sterile, gently rolling plains, with a slight and decreasing slope to the central Mississippi valley, interrupted by a range of low mountains, which form an extension southwestward of the Ozark mountains of southern Missouri. East of these mountains the country is low, rolling, and heavily timbered, finally descending to the level, alluvial plain through which the Mississippi flows. Here is a rich, black, alluvial soil, yielding generous crops of corn and cotton wherever cultivated.

13. *The upper Arkansas river.*—The Arkansas river has its source in central Colorado, near Leadville. Its course is easterly to the Great Bend in Kansas, where it sweeps northeast for a hundred miles, and then turns to the southeast to its confluence with the Mississippi in southeastern Arkansas. Its length is about 1,610 miles, and the distance from its source to the gulf of Mexico 2,290 miles. In the first 120 miles of its course the river is a clear, mountain stream, with rocky bed, descending nearly 5,000 feet in this distance. It escapes from the mountains through a magnificent gorge near Canyon City. In the vicinity of Pueblo, Colo., the width of the Arkansas is from 150 to 175 feet, and its depth from 3 to 5 feet. From Pueblo to the Great Bend its width gradually increases, from the addition of many small tributaries, to 500 or 600 feet. Through this sandy, arid region the stream is shallow, and its bed largely a quicksand; the banks are low, and beyond them spreads a grassy bottom, from a half mile to 2 miles in width between the bluffs. The latter rise from 50 to 300 feet, to the general surface of the rolling prairie. Passing around the Great Bend, the river turns southeast, and enters Oklahoma near its eastern border. In this portion, the river expands in width, in some reaches, to nearly a mile. Here it receives its first important tributary, the Cimarron. The discharge of the Arkansas river in low water is very small above the mouth of the Cimarron, and occasionally ceases entirely, there being few pools, even, to be seen.

14. *The lower Arkansas river.*—Below the mouth of the Cimarron the river changes in appearance; its water loses the pale, drab color it has previously possessed, and becomes an opaque red. The banks and bars are, from deposit, of the same hue. The stream becomes more serpentine in its course, and is obstructed by many sandbars and islands. Eighty miles below the Cimarron, the Canadian river is reached, the

most important tributary except the White river. This stream rises in the northeastern portion of New Mexico and is about 1,000 miles in length. Below the junction of the Canadian, the Arkansas enters the mountainous region, referred to above as extending across the basin from southern Missouri. Emerging from this broken country, the lower Arkansas is bordered by wide, alluvial bottoms, subject to overflow unless protected by levees. At Little Rock, Ark., there is to be seen a high bluff of slate, known as Big Rock, and a little below, on the opposite bank, a similar but smaller bluff known as Little Rock. These are the last outcroppings of the underlying rocks, and a short distance below them the valley merges into the wide, alluvial plain, which extends to the Mississippi. The White river is classed as a tributary of the Arkansas, although in many respects it is an independent stream, entering the Mississippi 8 miles above the mouth of the Arkansas. The latter is at Napoleon, Ark., but the Arkansas is connected, through a large bayou, with the White river, 6 miles above the mouth of the latter. Although draining a much smaller area than the Canadian, the White river supplies a far greater annual discharge, owing to a rainfall more than twice as great over its watershed. The Arkansas is navigable in high water to Fort Gibson, about 640 miles from the mouth and 1,320 miles from the gulf of Mexico. Its width in this reach is about 1,500 feet. The descent in the river, from Fort Gibson to the mouth, is approximately 400 feet, or an average of 0.62 foot per mile. The cross section in high water is about 70,000 square feet, at the mouth.

The Arkansas basin is conveniently divided into four districts, as shown on the drainage map, Plate I, and the areas of these subdivisions are given in the following table:

TABLE V.—*Subdivisions of the Arkansas basin.*

Designation.	Area in square miles.	Ratio to whole basin.
A	57,000	0.31
B	60,050	0.32
C	26,500	0.14
D	42,750	0.23
Total	186,300	1.00

RED BASIN.

15. *Character of the basin.*—The basin of the Red river is less than half the size of that of the Arkansas, but is similar to the latter in topography, except that its western limits lie to the south and east of the Rocky mountains. This portion of the basin forms a part of the desert plateau of *el Llano Estacado.* Eastward to the Cross Timbers the country is a barren gypsum desert for the most part. The Cross Timbers are an open forest of oak and blackjack, from 5 to 30 miles in width, and extending in a southwest direction from the Arkansas to the Brazos river. The Red river crosses this forest between longitude 97° and 98°. East of the Cross Timbers the transition is sudden to a fertile and well watered country, with abundant vegetation. The lower portion of the basin is low, and contains many swamps and bayous. The only mountainous regions, embraced in this drainage area, are the Wichita mountains in Oklahoma, west of the Cross Timbers, and the rugged district about the upper Ouachita.

16. *The Red river.*—The Red river rises in a ravine, some 60 miles in length, at the eastern rim of *el Llano Estacado.* Lofty sandstone walls rise precipitously to a height of 500 to 800 feet, springing almost from the river bank. The bluffs, into which this ravine is cut, rise abruptly from the lower prairie, and terminate at the summit in a level plateau, stretching south and west in desert sterility. The water of the river for 400 miles is bitter and nauseating from the salts held in solution. Soon after its débouché from *el Llano Estacado*, the river spreads out into a shallow stream, 2,000 to 2,500 feet in width, flowing rapidly over a sandy bed. Its first noteworthy tributary is the North Fork, which enters on the western borders of the Wichita mountains. East of the Cross Timbers the Washita unites with the Red river, and from this point the stream changes in character. It now flows through rich, alluvial bottoms, with a sluggish current, in a muddy bed. Its width contracts greatly, and ranges from 600 to 800 feet as far as the mouth of the Black, or 460 miles from its own mouth; at the latter point its width has again increased to 1,800 feet. The only tributary of great importance is the Black, which drains the Tensas bottom through bayou Tensas; this river is formed by the union of the Ouachita, Little river, and bayou Tensas, and is a deep, navigable stream, 54 miles long.

17. *Outlet bayous of the lower Red.*—From the source to the mouth of the Red river the distance is approximately 1,530 miles, and to the gulf of Mexico 1,840 miles. Just above Alexandria, La., at a distance of 139 miles from the mouth, the first bayou, the Rapides, is met. From this point to its mouth the Red river forms the northern boundary of the Delta. Bayou Atchafalaya leaves the river 7 miles above the mouth, and carries the main discharge of the Red to the Gulf, independently of the channel of the Mississippi. Numerous bayous connect the Atchafalaya with the Red at various points up to the Rapides. In times of high flood, water from the Mississippi enters the mouth of the Red, and is discharged through the Atchafalaya, thus reducing in some degree the height of the flood at points below on the Mississippi. The Red river is not therefore a true tributary of the Mississippi, but partakes largely of the character of an independent stream. The cross section of the lower river, in high water, is about 40,000 square feet. The river is navigable to Shreveport, La., except in extreme low water, and to Fulton, Ark., at a distance of 565 miles from its mouth, in high water. The descent in the river from the latter point is about 240 feet, or an average of 0.42 foot per mile.

The basin of the Red river may be divided into an upper and a lower section, as shown on the drainage map, Plate I, and the areas of these subdivisions are as follows:

TABLE VI.—*Subdivisions of the Red basin.*

Designation.	Area in square miles.	Ratio to whole basin.
A.	45,800	0.51
B.	44,200	0.49
Total	90,000	1.00

The upper portion of the basin is a region of very light precipitation, indeed, is a veritable desert. Its lower section, on the other hand, receives nearly the maximum

rainfall of the Mississippi basin. In the latter portion is included the great swamp known as the Tensas bottom, which is largely below the high-water level of the Mississippi, and is liable to overflow.

CENTRAL VALLEY.

18. *Extent of the Central Valley.*—Under the designation of the Central Valley, have been included the many small basins which are drained by direct tributaries of the Mississippi, south of the Missouri. Together they form a strip of country, nowhere exceeding 200 miles in width, and terminating in the Delta. The only important streams among these tributaries are the St. Francis and the Yazoo, which drain the two great bottoms of the same names. The total area included in the Central Valley, is only three-fourths that of the Red river basin, making it the smallest of the six grand divisions of the Mississippi basin. The annual precipitation, however, over this region, is heavy, and the water courses short, and, as a result, its contribution to the Mississippi discharge is exceeded only by that of the Ohio.

19. *Basins of the Kaskaskia and Meramec rivers.*—The Central Valley is naturally divided into six districts. The first, descending the Mississippi, is the country extending from the mouth of the Missouri river to Cape Girardeau, Mo., on the right bank, and to the mouth of the Ohio on the left bank. This is designated as A upon the drainage map. The chief stream on the right bank is the Meramec, which drains the northeast slope of the Ozark mountains, and enters the Mississippi about 25 miles below St. Louis. Smaller creeks drain the land immediately adjacent to the Mississippi, south of the Meramec. This whole region is hilly, and contains no land liable to inundation. On the left bank the most important stream is the Kaskaskia, which joins the Mississippi 50 miles below the Meramec. Between the mouth of the Missouri and that of the Kaskaskia is the American bottom, which is flooded in very high water. A smaller strip of land, bordering the Mississippi above Cairo, is also subject to inundation. The Kaskaskia itself flows through an alluvial bottom, which is overflowed in freshets.

20. *Basin of the St. Francis river.*—From Cape Girardeau, Mo., to Helena, Ark., the right bank of the Mississippi bounds what is known as the St. Francis basin, although some small areas are drained by other streams than the St. Francis. This forms the second natural division of the Central Valley, and is designated as B upon the drainage map. Two-thirds of this entire area of 10,500 square miles is included in the St. Francis bottom; the remainder is a broken, hilly country, forming a portion of the southern slope of the Ozark mountains, and descending rapidly to the bottom lands. Just below Cape Girardeau there is a strip of low land for 4 miles along the right bank of the Mississippi, over which flood water flows into the St. Francis bottom; this is the northern limit of the swamp region. The bluff reappears at Grays Point and continues for 7 miles to Commerce, Mo. From the latter point to the lower end of the St. Francis basin at Helena, Ark., the right bank of the Mississippi is low, except at New Madrid, Mo. At this point the Mississippi cuts through a low ridge, which is the continuation southward of the Commerce bluffs. The high land at Cape Girardeau extends in a long range of low hills, known in different parts as Hickory ridge, Bloomfield ridge, and Crowleys ridge, at first southwest and then south to Helena. These hills, from 200 to 400 feet in height, form the western boundary of the St. Francis bottom. Near their northern end they are pierced by the White and Castor rivers, and a little farther

south by the St. Francis. The latter stream, after piercing the hills at Chalk bluff, flows southward, close to their base, to its mouth, 9 miles above Helena.

21. *St. Francis bottom.*—The swamp known as the St. Francis bottom, is a great plain, which extends from the bounding, western ridge to the Mississippi. It is nearly level, but slopes toward the west, or *away from the Mississippi river*, with an average gradient of about 0.5 foot to the mile; from north to south there is a slightly greater descent of about 0.7 foot per mile. Some small ridges cross the swamp, and are above overflow, but, for the most part, the entire area would be submerged in floods, unless protected by levees. The extent of country liable to inundation is about 6,090 square miles. From Point Pleasant, Mo., southward for 125 miles, a levee now borders the river; the remaining front of the St. Francis bottom is not leveed. The building of this levee has had an important effect upon the regimen of the St. Francis river. Before its construction, many bayous gave entrance for the Mississippi water to the swamp, long before the crest of the flood was reached. The swamp, thus filled, drained into the St. Francis, and, when the flood crest in the Mississippi reached Helena, the St. Francis would also be in high flood, and would add large quantities of water to the Mississippi flood at its top. Since the building of the levee this action is much reduced, and it sometimes happens, in rapid rises of the Mississippi, that the current of the St. Francis is reversed, and the river backed up as far as Wittsburg, a distance of 80 miles. At the same time, the water which is retained in the Mississippi, causes the crest of the main flood to be higher at Memphis and Helena. It seems, from the records of the flood of this year, that the latter effect is the greater, and that the total effect of the levee has been to cause decidedly higher water at the head of the Yazoo bottom.

22. *Basins of the Obion and Hatchee rivers.*—On the left bank, from Cairo, Ill., to a few miles below Memphis, Tenn., the bluffs are nowhere far removed from the Mississippi. They touch the river at Columbus and Hickman, Ky., distant 21 and 36 miles, respectively, from Cairo. Again, between New Madrid and Point Pleasant, Mo., the bank is high, the river here intersecting the ridge before noted as extending south from the Commerce bluffs. Below this point the four Chickasaw bluffs, on the fourth of which Memphis is built, approach the river. The region back of the bluffs is mostly hilly, and is drained by many small rivers and creeks. The more important of these streams are the Obion, the Forked Deer, the Hatchee, and the Wolf. This entire drainage area, designated as C upon the drainage map, between the Ohio river and the Yazoo bottom, comprises about 10,250 square miles, of which little more than 600 are liable to inundation.

23. *Basin of the Yazoo river.*—From the Tennessee-Mississippi boundary line, 18 miles by river below Memphis, to Vicksburg, the Mississippi river borders the Yazoo bottom. The latter is a heavily timbered, alluvial plain of oval shape, about 180 miles in length, and 70 miles in width at its widest part. Like the St. Francis bottom, it slopes *away from the Mississippi river*, and descends toward the south. The gradient is less than in the former bottom, being on an average 0.4 foot per mile from west to east and 0.6 from north to south. On its eastern side the swamp is bounded by a line of hills, close to which flows the main stream, which drains this region. In its upper portion this river is known as the Coldwater, and, below the confluence of the Tallahatchie, as the Yazoo. The total length of the stream is some 500 miles, and it is navigable throughout the year to Greenwood, Miss., about 240 miles from the mouth. Including

the upland, the total area drained by the Yazoo is about 13,850 square miles; the bottom embraces 6,650 square miles subject to overflow. This basin is designated as D on the drainage map.

24. *The Yazoo bottom.*—The Yazoo bottom is traversed by a ridge from 2 to 6 miles in width, and above overflow. This forms an extension southward of Crowleys ridge, and stretches almost entirely across the bottom from Delta, Miss., on the Mississippi river, south of Helena. With this exception, the entire bottom is liable to submergence in times of flood, save as it is protected by levees. At the present time the entire front has been leveed, from the northern boundary of Mississippi to a point 13 miles above Vicksburg, a distance by river of 336 miles. The construction of the levee has produced a change in the regimen of the Yazoo river similar to that in the case of the St. Francis. In former times the Yazoo bottom began to fill when the Mississippi was as much as 10 feet below the maximum flood height, and the Yazoo river discharged a large volume of water, even at the top of the highest floods. At present, while the levees remain unbroken, the Yazoo is backed up by a Mississippi flood—sometimes, in rapid rises, for as much as 70 miles from its mouth—unless there be at the same time a local freshet in its tributaries, when it may maintain a moderate discharge. In rare instances there is even a reversed current of water from the Mississippi.

25. *The Tensas bottom.*—From the southern border of the St. Francis basin to the Red river, the country bordering the right bank of the Mississippi is included in the Arkansas and Red basins, which we have already considered. This land is all low, and embraces the Tensas bottom, about 4,955 square miles in extent, and similar in character to the St. Francis and Yazoo bottoms. This great swamp is chiefly drained by bayou Tensas, which unites with the Ouachita and Little rivers to form the Black, the most important tributary of the Red.

26. *Basins of the Big Black and Homochitto rivers.*—Between Vicksburg, Miss., and Baton Rouge, La., several small tributaries enter the Mississippi on the left bank, the larger of which are the Big Black and the Homochitto. Except a narrow strip of low land immediately bordering the river, this drainage area is rolling and hilly; bluffs, from 100 to 300 feet in height, are met at a short distance from the river. Of its total area of about 7,250 square miles, not more than 415 are liable to overflow. At several points the bluffs extend clear to the river, notably at Natchez, Fort Adams, and Port Hudson. This drainage area is shown on the map as section E of the Central Valley.

27. *Extent of the Delta.*—Considering the location of the general coast line of the gulf of Mexico, and the geological formation of the soil, as shown from various borings, the conclusion is reached that the true delta of the Mississippi begins not far from the head of the former bayou Plaquemine, now closed. This would make the advance of the river mouth into the gulf some 220 miles. It is customary, however, to designate by the term *Delta* all that alluvial region which stretches southward from the Red river. The northern and eastern boundary of this region begins at bayou Rapides on the Red river, and follows the latter to its mouth; from the latter point to bayou Manchac, 14 miles below Baton Rouge, the Mississippi forms the boundary; descending bayou Manchac to the Amite river, and the latter to its mouth, the boundary then follows the southern shore of lakes Maurepas, Pontchartrain, and Borgne, and their connecting passes, to the gulf of Mexico. From lake Borgne on the east to Vermillion bay on the

west, the coast line bounds the Delta, and thence the boundary extends northwestward to its initial point on Red river. The area embraced in the Delta is designated on the drainage map as section F of the Central Valley.

28. *Character of the Delta.*—With the exception of a small area of higher ground, known as Avoyelles Prairie, near the Red river, and the prairies along bayou Teche, this entire section, designated as F on the drainage map, 12,300 square miles in extent, is a low, swampy region, intersected by countless bayous. Fully 4,000 square miles are a sea marsh, and above 10,000 are liable to overflow. The main drain of the Delta is bayou Atchafalaya, which leaves the Red river 7 miles from its mouth, and, flowing southward through Grand lake, finally reaches the sea at Atchafalaya bay. Formerly, bayou Plaquemine left the Mississippi 20 miles below Baton Rouge, and connected with the Atchafalaya through Grand river, but this bayou has now been closed by the Mississippi levee. Thirty-three miles farther down and 80 miles above New Orleans, the second great drain of the Delta, known as bayou La Fourche, leaves the Mississippi at Donaldsonville, La. This flows south and southeast to the sea, its mouth being midway between those of the Atchafalaya and the Mississippi. At the western edge of the Delta, bayou Teche at the south and bayou Bœuf farther north, together with bayou Rapides, form a second drainage line from the Red to the Atchafalaya near its mouth, and the intervening region is covered by a network of intercommunicating bayous, connected with the Red river at several points between bayous Rapides and Atchafalaya.

29. *General features of the Central Valley.*—The various divisions of the Central Valley have now been considered briefly. The entire valley has an abundant annual precipitation, which grows heavier as we proceed toward the south. On its southern extremity the maximum precipitation of the Mississippi drainage basin falls, amounting to 60 inches in the year. Of the entire area of 69,000 square miles included in the Central Valley, 30,000 square miles are alluvial land, covered with river sediment, and subject to overflow, except as protected by artificial means. The areas of the various subdivisions are shown in the following table:

TABLE VII.—*Subdivisions of the Central Valley.*

Designation.	Area in square miles.	Ratio to whole basin.
A	14,850	0.22
B	10,500	0.15
C	10,250	0.15
D	13,850	0.20
E	7,250	0.10
F	12,300	0.18
Total	69,000	1.00

LOWER MISSISSIPPI RIVER.

30. *The alluvial plain.*—From the mouth of the Missouri to the gulf of Mexico, a distance by water of 1,280 miles, the river is designated as the Lower Mississippi, to distinguish this portion from the Upper Mississippi, which, as before remarked, is rather a tributary than a part of the main stream. For most of this distance the river's course is through an alluvial plain, covered to no great depth with sedimentary deposits

of the stream. The extent of this alluvial region is shown by the lighter tint on Plate II, as it has been laid down on the large map, published in 1887 by the Mississippi River Commission. The alluvion rarely exceeds 40 feet in depth, and is everywhere underlaid by a hard, tenacious, blue clay, below which is found water-bearing gravel and sand. In many instances there are alternate strata of clay and gravel. The bed of the river from the mouth of the Ohio to the gulf of Mexico is in this blue clay. The immediate banks of the river are higher than the land farther back, which is, for the most part, below the high-water level. The slope is greatest near the river, being from 3 to 12 feet in the first mile, and averaging perhaps 7; it then diminishes until the almost level swamp is reached, at a distance of 2 or 3 miles from the river.

31. *Character of the Lower Mississippi river.*—The head of the alluvial plain is at Cape Girardeau, Mo., where the highlands of the upper river cease for a distance of 4 miles, to reappear for a short distance as the Commerce bluffs. Below the latter, the Mississippi touches high land on its right bank at only two points, New Madrid, Mo., and Helena., Ark. On the left bank, high land approaches the river at Columbus and Hickman, Ky., at the four Chickasaw bluffs, and at several points from Vicksburg, Miss., to Baton Rouge, La. The direct distance from the head of the alluvial plain to the mouth of the Mississippi is less than 600 miles, but, by the tortuous river channel, it exceeds 1,100 miles. The river is turbid with a yellowish mud, the sediment carried being stated by Humphreys and Abbot as $\frac{1}{1500}$ part of the river water by weight. The total transport of earthy matter to the sea is, approximately, 400,000,000 tons per year. The Lower Mississippi is a turbulent stream, eating away its banks in the bends, building and destroying islands and bars in its channel. The caving of its banks is occasioned by the peculiar formation of the soil, already noted; the underlying sand and gravel is washed out, and then the overlying stratum of clay falls of its own weight, and is dissolved by the swift current.

32. *Dimensions of the river.*—In its course through the alluvial plain, the Mississippi decreases in width and increases in depth, while its cross section changes but slightly. The following table, compiled by Humphreys and Abbot, from accurate measurements, is taken from their report:

TABLE VIII.—*Mean dimensions of the Lower Mississippi.*

Locality.	High water.			Low water.		
	Cross section.	Width.	Maximum depth.	Cross section.	Width.	Maximum depth.
	Square feet.	*Feet.*	*Feet.*	*Square feet.*	*Feet.*	*Feet.*
Cairo to Arkansas river	191,000	4,470	87	45,000	3,400	49
Arkansas river to Red river	199,000	4,080	96	54,000	3,060	56
Red river to bayou La Fourche	200,000	3,000	113	100,000	2,750	78
Bayou La Fourche to head of passes	199,000	2,470	129	163,000	2,250	114

33. *Slope of the water surface.*—River gauges have been established at various points along the Lower Mississippi, and the height of the water surface thereon has been observed for periods of from twenty-five to thirty-five years. The elevation of the gauges above sea level has been determined through precise surveys by the United States engineers. From these gauge readings there has been computed the average

stage of water at certain points, and this, referred to sea level, enables us to determine the average slope of the river. The resultant data are given in the following table:

TABLE IX.—*Mean slope of the Lower Mississippi.*

Stations.	Mean stage above sea level.	Distance between stations.	Average slope per mile, between stations.
	Feet.	*Miles.*	*Foot.*
St. Louis, Mo.	391.6		
		191	0.528
Cairo, Ill.	290.8		
		230	0.403
Memphis, Tenn.	198.1		
		369	0.353
Vicksburg, Miss.	67.9		
		358	0.173
Carrollton, La.	6.1		

It will be observed that the slope steadily diminishes as the gulf is approached. During the remaining 116 miles from Carrollton to the gulf the slope is very slight.

34. *Mouths of the Mississippi.*—The waters of the Mississippi are discharged through several mouths, and across a true delta. From the last outlet bayou, La Fourche, to Fort St. Phillip, the channel is nearly uniform, averaging in high water 199,000 square feet in cross section, 2,470 feet in width, and 129 feet in maximum depth; these dimensions become in low water 163,000 square feet, 2,250 feet, and 114 feet, respectively. Twenty miles below Fort St. Phillip, at the head of the passes, the river spreads out to a width of 7,000 or 8,000 feet, its maximum depth decreases to about 40 feet, and its cross section becomes 250,000 square feet. It then divides into three branches, two of which flow direct to the sea, and are known as the Southwest and the South pass, respectively. The third subdivides, 5 miles from its head, and finally reaches the sea by five mouths, known as Balize bayou, Southeast pass, Northeast pass, pass a l'Outre, and North pass. There are also three small outlets above the main passes. Midway between Fort St. Phillip and the head of the passes are found two small outlets, the Jump on the west and Baptiste Collet bayou on the east side; and about 2 miles above the head of the passes another small outlet, known as Cubits Gap, occurs on the east side.

35. *Mississippi levees.*—From Fort St. Phillip, 20 miles above the head of the passes, to Baton Rouge, the river is leveed on both sides. On the east bank there is no levee above Baton Rouge until that in front of the Yazoo bottom is reached. On the west bank the levee continues to the Red river, and is resumed 30 miles above the latter. Thence it extends to a point 25 miles below the Arkansas river, and is again resumed a few miles above, continuing to Helena, Ark. One hundred and six miles farther upstream the St. Francis levee begins, and extends to Point Pleasant, Mo.

SECTION II.

NORMAL PRECIPITATION AND DRAINAGE.

Relation of downfall and drainage.—Method of determining downfall.—Errors in hyetal measurements.—Magnitude of rain-guage errors.—Cause of error is the wind.—Proper method of determining normal precipitation.—The isohyetal charts.—Geographical distribution of precipitation.—Seasonal changes in distribution.—Method of computing precipitation on a watershed.—Average precipitation on the various watersheds.—Downfall in the six chief divisions of the Mississippi basin.—Determination of discharge.—Available data.—Computation of normal discharge.—Remarks upon the computed discharges.—Differences in normal drainage.—Measurement of the stage of a river.—Stations selected for study.—Method of computing normals.—Normal regimen of the rivers.—Mean and extreme river stages.—Normal monthly stages.

THE water discharged from a river basin is derived entirely from the precipitation falling over it. Of the total downfall of water, a part flows off upon the surface of the ground to the small rivulets and drains, ultimately reaching the main river of the basin. The remainder sinks into the ground, and is partly absorbed by vegetation, partly evaporated, and in part sinks until it reaches the impervious rock, which lies at no great depth below the surface. Along this rock it slowly flows down the slope, and gives rise to the springs which supply the steady flow of the stream. Floods and freshets have their origin in the surface discharge, while the low-water flow of streams is chiefly due to the underground waters. The relation of downfall to drainage will vary with the character of the soil and vegetation, and the steepness of the surface slope. In a region like the dry western plains of the Missouri valley, which is level and sandy, and over which the precipitation is deficient, the proportion of the downfall that reaches the river will be small. On the other hand, in a region like the Yazoo bottom, which remains almost saturated with moisture at all times and is densely shaded by vegetation, and where, moreover, the rainfall is excessive, a large portion of the downfall will be discharged.

36. *Method of determining downfall.*—In investigating a river system, it is of prime importance to ascertain the downfall of water over the area drained. For this purpose it is necessary to know the area of the watershed and the depth of precipitation which falls upon it. Probably no other meteorological element has been made the subject of more frequent observation than the precipitation, and yet it is doubtful if the true normal rainfall is known at any point of the earth's surface within 3 per cent, or perhaps an inch in an annual amount such as falls in the eastern part of the United States. We possess a number of records of precipitation covering a period in excess of half a century, and many exceeding thirty years in length. As records of the *catch of water* by a certain gauge in a certain location, some of these records are admirable. There are,

however, certain inherent errors in the ordinary methods of measuring precipitation, which have received too little consideration at the hands of meteorologists.

MEASUREMENT OF PRECIPITATION.

37. *Errors in hyetal measurements.*—So important is the matter of errors in the measurement of precipitation that it merits a moment's consideration. The practically universal method of measurement is by exposing in an open place a cylindrical vessel of moderate size, usually 4 to 8 inches in diameter and relatively deep. The measured precipitation has been shown to be liable to error from two sources, one arising from the gauge itself and the other from its environment. The error from both sources is due to irregular eddies and currents of wind, caused in the one case by the obstruction to the wind of the gauge itself, and in the other by the more or less close proximity of trees, buildings, or other irregularities of the surface. The effect is the greater, the greater the velocity of the wind, and hence increases with altitude above the surface, because the wind velocity is greater at higher elevations.

38. *Magnitude of rain-gauge errors.*—This matter has been treated at length by Professor Abbe, in Bulletin No. 7, Forestry Division, Department of Agriculture, in which anyone interested in the subject may find a more detailed discussion of the errors in the measurement of precipitation. The following table, first given by Wild, is taken from this bulletin and shows the great inaccuracy of measurement with the usual form of gauge:

TABLE X.—*Deficits of rain-gauge catch.*

Altitude of gauge.	Low wind velocities—4 to 11 miles per hour.		High wind velocities—12 to 20 miles per hour.	
	Rainfall.	Snowfall.	Rainfall.	Snowfall.
Feet.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3	5	11	6	14
7	8	14	16	18
80	19	74	44	84

The effect of the error arising from the gauge itself is always to give too small a catch, the deficit with the usual gauge, in a lengthy period, seemingly never being less than 5 per cent. The table also shows that the deficit is much greater in the case of snow than in that of rain, and it has further been shown by Bornstein that the deficit is greater in a fine than in a heavy rain. The effect of environment may be either to increase or diminish the catch, and hence the combined effect of the two sources of error may be to make the catch either exceed or fall short of the true precipitation, and by as much as 25 per cent in extreme cases. The effect of environment has been investigated by Hellmann at eleven stations in and about Berlin, with gauges exposed at each after a uniform plan. All the gauges were at a fixed height of 42 inches above the ground, and were situated in open places; in other words, the gauges were vastly more uniform in exposure than those whose records we are to discuss, and their mutual variations must be attributed to environment. The results of observations for two full years showed departures in the annual catch of individual gauges, from the mean catch

of the whole eleven, of as much as 14 per cent. The probable error in the annual rainfall, as determined by any single gauge, is found to be 6 per cent.

39. *Cause of error is the wind.*—Professor Abbe sums up the conclusions to be drawn from these observations of Hellmann, as follows:

Instead of studying the geographical or horizontal distribution of the total annual rainfall, it is safe to assume that that had been uniform for each year over this small area, and that we are studying simply the horizontal distribution of a deficiency in catch, or a rain-gauge error due to very local winds at the mouths of the gauges. This conclusion is confirmed by examining the records in the summer months separately from those in the winter. Local showers are frequent during the summer, and irregularities in horizontal distribution are presumptively greater at that time. During the winter the extended layers of clouds give us no *a priori* reason to expect large irregularities in the geographical distribution of snowfall and rain. Hellmann's records show that the geographical irregularities in the catch of his gauges are really least in summer and greatest in winter, thus confirming our convictions that on the average of the year the precipitation is uniformly distributed, and the variations in catch depend on the geographical distribution of the wind at the gauges during the fall of rain and snow.

NORMAL AMOUNT OF PRECIPITATION.

40. *Proper method of determining normal precipitation.*—Errors of the very considerable magnitude which we have noted above, are possible in any record of precipitation which we possess. We can, therefore, arrive at a rational idea of the normal distribution of precipitation over the United States only by a process of mutual adjustment of measured amounts at the different observation stations, and must beware of giving close details based on a single record. This method has been followed in the preparation of the normal monthly and annual charts of precipitation, Plates IV to XVI. The normal data on which these charts are based have been collected by the Division of Records and Meteorological Data of the Weather Bureau, and are given in full in the following table:

TABLE XI.—*Normal monthly and annual precipitation.*

OHIO DRAINAGE BASIN.

Stations.	Latitude.		Longitude.		Years of record.	Precipitation in inches.												
						January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	°	′	°	′														
Cairo, Ill	37	00	89	10	25	3.7	3.9	3.8	3.8	4.1	4.4	3.4	2.8	2.6	2.7	4.2	3.2	42.6
Indianapolis, Ind	39	46	86	10	27	2.9	3.4	3.6	3.6	4.0	4.5	4.2	3.3	3.1	2.8	3.8	3.0	42.2
Bowling Green, Ky	36	58	86	25	10	4.2	5.0	4.7	4.9	4.5	4.0	4.3	4.1	2.7	2.5	4.6	3.4	48.9
Lexington, Ky	38	02	84	33	11	4.1	3.5	4.7	3.8	3.4	4.2	4.7	3.6	2.6	2.5	3.6	3.3	44.0
Louisville, Ky	38	15	85	45	54	3.7	4.0	4.4	4.2	4.1	4.7	4.1	3.8	3.0	2.9	3.9	4.4	47.2
Murphy, N. C	35	05	84	02	16	6.2	6.3	6.0	5.0	3.2	5.4	6.5	5.3	3.5	3.1	4.5	5.2	60.2
Cincinnati, Ohio	39	06	84	30	62	3.3	3.3	3.5	3.3	4.0	4.4	3.9	3.8	3.0	2.8	3.3	3.5	42.1
Kenton, Ohio	40	40	83	33	15	3.8	3.3	5.1	3.9	6.0	5.6	5.1	4.4	3.1	2.7	3.8	3.8	50.6
Marietta, Ohio	39	28	81	26	69	3.1	3.1	3.2	3.3	3.9	4.1	4.4	3.9	3.1	3.1	3.1	3.4	41.7
North Lewisburg, Ohio	40	12	83	32	25	3.6	3.5	3.2	3.1	3.9	4.0	4.4	3.3	3.2	2.2	3.3	2.8	40.5
Portsmouth, Ohio	38	42	82	53	63	3.5	3.2	3.5	3.2	3.5	4.0	3.9	3.4	2.8	2.8	2.9	3.5	40.2
Confluence, Pa	39	48	79	21	21	4.0	3.9	3.5	3.4	4.0	4.4	4.6	3.7	3.1	2.9	3.2	3.6	44.3
Pittsburg, Pa	40	32	80	02	54	2.6	2.5	2.8	3.0	3.5	3.6	4.0	3.4	2.9	2.8	2.6	2.9	36.6
Chattanooga, Tenn	35	04	85	15	18	6.4	5.6	5.8	4.5	4.1	4.7	4.1	4.1	3.7	2.6	4.0	4.3	53.9
Knoxville, Tenn	35	56	83	58	26	5.3	5.3	5.4	4.9	4.0	4.2	4.4	4.0	2.7	2.7	3.8	3.9	50.6
Nashville, Tenn	36	09	86	49	32	5.0	5.0	5.2	4.7	3.9	4.3	4.3	3.6	4.1	2.7	3.9	3.5	50.2
Wytheville, Va	36	55	81	02	26	3.4	3.3	3.4	3.4	3.7	4.0	4.0	4.0	3.7	3.0	2.6	2.8	41.3

TABLE XI.—*Normal monthly and annual precipitation*—Continued.

Stations.	Latitude.	Longitude.	Years of record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	° ′	° ′		Precipitation in inches.												
UPPER MISSISSIPPI DRAINAGE BASIN.																
Marengo, Ill.	42 15	88 37	45	1.9	1.9	2.4	2.8	3.9	4.3	3.7	3.7	3.8	2.4	2.2	1.9	34.9
Peoria, Ill.	40 42	89 36	41	1.7	2.0	2.6	3.2	3.8	3.7	4.0	3.0	3.5	2.4	2.4	2.3	34.6
Ames, Iowa	42 03	93 38	21	1.0	0.8	1.6	2.9	4.1	4.4	4.7	3.4	3.0	2.3	1.3	1.1	31.2
Cresco, Iowa	43 22	92 07	25	1.3	0.9	1.8	2.6	3.8	5.0	3.9	2.8	3.6	2.3	1.5	1.4	30.9
Davenport, Iowa	41 30	90 38	26	1.7	1.6	2.2	2.8	4.2	4.2	3.6	3.6	3.2	2.6	2.0	1.6	33.3
Keokuk, Iowa	40 22	91 26	24	1.7	1.7	2.2	3.2	4.1	4.5	4.1	2.8	3.5	2.8	2.1	2.0	34.7
Monticello, Iowa	42 13	91 15	42	1.6	1.7	2.4	2.6	3.9	4.5	4.2	3.7	3.8	2.8	2.3	2.3	35.8
Fort Riley, Kans	39 02	96 45	39	0.6	0.9	1.0	2.0	3.4	3.9	3.7	3.7	2.8	1.6	1.2	0.8	25.6
Fort Ripley, Minn	46 10	94 24	27	0.8	0.9	1.5	1.8	3.2	4.3	4.0	3.3	3.1	1.6	1.6	0.9	27.0
St. Paul, Minn	44 56	93 05	39	1.0	0.9	1.5	2.5	3.5	4.1	3.3	3.8	3.2	2.0	1.3	1.1	28.2
La Crosse, Wis	43 49	91 15	24	1.2	1.1	1.5	2.4	3.3	4.5	4.0	3.2	4.2	2.3	1.6	1.4	30.7
Madison, Wis	43 05	89 24	28	1.8	1.7	2.4	2.6	3.5	4.5	4.0	3.1	3.1	2.6	1.9	2.0	33.2
MISSOURI DRAINAGE BASIN.																
Denver, Colo	39 45	105 00	27	0.6	0.5	1.0	2.0	2.7	1.3	1.7	1.4	0.9	0.9	0.7	0.6	14.3
Fort Collins, Colo	40 35	105 02	10	0.7	0.6	0.8	1.7	2.9	1.7	1.8	1.3	0.9	0.9	0.4	0.3	14.0
Lawrence, Kans	38 58	95 14	31	1.2	1.4	2.3	3.2	4.6	5.0	4.7	3.9	3.5	2.7	1.8	1.6	35.9
Hermann, Mo	38 41	91 28	14	2.2	2.8	3.2	3.4	4.6	5.1	3.7	2.9	3.7	2.0	3.2	2.1	38.9
Miami, Mo	39 18	93 15	49	1.7	1.7	2.4	3.0	4.2	5.0	4.2	3.6	3.4	2.8	2.1	2.0	36.1
Oregon, Mo	40 02	95 09	41	1.6	1.8	2.0	3.3	4.7	4.7	4.3	4.3	3.1	2.6	1.7	1.6	35.7
Rolla, Mo	37 56	91 32	10	2.2	2.9	3.3	5.2	5.1	4.1	5.0	3.4	3.2	2.3	2.3	2.3	41.3
St. Louis, Mo	38 37	90 12	60	2.2	2.7	3.4	3.7	4.7	5.0	3.8	3.5	3.1	2.8	3.1	2.8	40.8
Fort Keogh, Mont	46 22	105 56	19	0.6	0.5	0.6	1.1	2.2	2.8	1.2	0.9	0.8	1.0	0.5	0.4	12.6
Havre, Mont	48 32	109 42	16	0.9	0.5	0.5	1.0	1.7	3.1	2.1	1.4	1.2	0.6	0.7	0.5	14.2
Helena, Mont	46 34	112 04	15	1.3	0.7	0.7	1.1	1.6	2.3	1.1	0.6	1.2	0.9	0.8	0.9	13.2
Virginia City, Mont	45 10	112 00	16	0.6	0.6	1.0	1.2	2.7	2.3	1.4	1.2	1.3	0.8	0.7	0.8	14.6
Genoa, Nebr	41 25	97 40	21	0.9	0.8	1.2	2.9	4.1	4.5	3.9	2.5	2.8	1.5	0.8	0.9	26.8
Minden, Nebr	40 30	98 56	18	1.1	1.2	1.5	3.5	5.3	5.4	5.2	3.2	2.4	1.8	0.9	0.8	32.3
North Platte, Nebr	41 08	100 45	29	0.4	0.4	0.7	2.1	3.0	3.5	2.5	2.3	1.5	0.8	0.4	0.5	18.1
Omaha, Nebr	41 16	95 56	27	0.7	0.7	1.5	3.1	4.5	5.3	4.6	3.3	3.0	2.6	1.1	1.0	31.4
Bismarck, N. Dak	46 47	100 38	22	0.6	0.6	1.1	2.3	2.5	3.5	2.3	2.0	1.2	1.0	0.8	0.6	18.5
Fort Buford, N. Dak	48 00	103 55	29	0.6	0.5	0.6	1.2	2.4	2.8	1.7	1.2	0.8	0.8	0.6	0.6	13.8
Fort Meade, S. Dak	44 26	103 28	16	0.8	0.5	1.4	2.8	3.5	3.3	1.9	1.7	0.6	0.9	0.7	0.6	18.7
Fort Sully, S. Dak	44 39	100 39	25	0.5	0.4	1.2	2.1	2.6	3.3	2.7	1.9	0.9	0.7	0.4	0.5	17.2
Huron, S. Dak	44 21	98 09	14	0.5	0.6	0.9	2.9	3.0	3.6	3.1	2.6	1.4	1.2	0.6	0.6	21.0
Yankton, S. Dak	42 54	97 28	20	0.6	0.8	1.2	3.3	4.0	4.1	3.5	3.0	2.6	1.3	0.6	0.8	25.8
Cheyenne, Wyo	41 08	104 48	27	0.4	0.4	0.8	1.5	2.3	1.5	1.9	1.6	1.0	0.7	0.3	0.3	12.7
Fort Washakie, Wyo	42 30	108 53	12	0.6	0.4	1.5	2.1	2.2	1.0	0.8	0.6	0.5	0.8	0.7	0.4	11.6
ARKANSAS DRAINAGE BASIN.																
Fort Smith, Ark	35 23	94 29	33	2.1	3.1	2.9	4.8	4.7	4.2	3.9	3.4	3.1	3.2	3.6	2.7	41.7
Lead Hill, Ark	36 29	92 45	15	2.7	4.1	4.1	4.2	6.0	4.8	5.2	4.7	4.0	3.5	3.8	4.3	51.4
Little Rock, Ark	34 45	92 06	16	4.9	5.3	5.2	4.8	5.8	4.3	4.0	4.1	3.2	2.5	5.3	4.3	53.7
Colorado Springs, Colo	38 51	104 47	12	0.2	0.3	0.6	1.4	2.4	1.9	3.2	2.2	1.1	0.6	0.3	0.3	14.5
Las Animas, Colo	38 04	103 12	12	0.3	0.4	0.6	1.1	1.9	1.4	1.6	1.6	0.6	0.5	0.2	0.6	10.8
Fort Gibson, Ind. T	35 50	95 20	29	2.1	2.2	2.5	4.1	4.5	3.9	2.7	2.8	2.7	3.4	2.9	2.1	35.9
Dodge City, Kans	37 45	100 00	22	0.4	0.6	0.9	1.8	3.1	3.3	3.2	2.8	1.3	1.3	0.5	0.6	19.8
Independence, Kans	37 13	95 41	25	1.6	2.0	2.2	3.7	4.6	4.9	4.2	3.0	3.7	2.7	1.8	2.3	36.7
DRAINAGE BASIN OF THE RED.																
Washington, Ark	33 34	93 41	27	4.8	4.7	5.6	6.0	5.2	3.9	4.7	3.9	3.1	3.6	4.9	4.4	54.8
Fort Sill, Ind. T	34 40	98 23	24	1.2	1.2	1.5	2.7	4.4	3.7	2.9	3.2	2.8	2.7	1.5	1.9	29.7
Shreveport, La	32 30	93 40	25	4.7	4.2	4.6	5.2	4.2	3.7	3.4	2.1	3.7	3.2	4.7	4.5	48.2
Fort Elliott, Tex	35 30	100 21	11	0.6	0.5	0.6	2.6	4.4	3.2	2.3	3.3	1.8	2.5	0.6	0.7	23.1
CENTRAL VALLEY.																
Helena, Ark	34 33	90 36	20	6.1	5.2	6.6	6.7	4.5	4.7	4.5	3.5	3.9	2.4	4.8	4.6	57.5
Mattoon, Ill	39 29	88 24	15	2.5	3.8	3.4	4.2	5.0	4.8	3.9	3.4	2.9	2.8	3.4	2.7	42.8
Baton Rouge, La	30 25	91 05	24	5.1	4.6	5.0	4.7	4.5	5.0	6.3	5.9	4.2	3.2	5.5	5.6	59.6
New Orleans, La	29 58	90 04	26	5.1	4.4	5.3	5.2	4.8	6.7	6.4	6.0	4.6	3.3	4.1	4.4	60.3
Brookhaven, Miss	31 34	90 29	12	4.9	5.6	6.7	6.9	4.6	5.6	5.7	5.6	3.7	2.5	4.1	5.0	60.9
Vicksburg, Miss	32 23	90 50	42	5.3	4.9	5.5	5.3	4.4	3.9	4.5	3.4	3.3	2.6	4.7	4.9	52.7
Memphis, Tenn	35 09	90 03	26	5.5	5.2	5.9	5.4	4.4	4.6	3.4	3.5	3.1	2.7	4.8	4.1	52.6
DRAINAGE TO THE ATLANTIC OCEAN.																
Hartford, Conn	41 25	72 40	27	4.3	4.0	4.2	3.0	3.6	3.0	4.1	4.6	3.2	3.9	3.8	3.6	45.3
New Haven, Conn	41 18	72 56	45	3.8	4.0	3.8	3.3	3.9	3.1	4.5	4.6	3.5	3.8	3.8	3.4	45.8
Washington, D. C	38 54	77 03	41	3.4	3.1	3.9	3.4	4.1	3.9	4.5	4.0	3.5	3.3	2.7	3.1	42.9
Jacksonville, Fla	30 20	81 39	27	3.1	3.0	3.6	2.7	3.8	6.1	6.2	6.7	8.2	5.2	2.7	2.8	54.1
Augusta, Ga	33 28	81 54	27	4.5	4.0	5.1	3.4	3.4	4.6	5.4	5.0	3.7	2.5	3.0	3.4	48.0
Savannah, Ga	32 05	81 05	48	3.1	2.8	3.7	2.7	3.8	5.8	6.6	7.8	5.2	3.0	2.0	3.5	50.0
Gardiner, Me	44 14	69 48	53	3.6	3.5	3.9	3.4	3.8	3.2	3.2	3.6	3.2	4.1	4.0	3.8	43.3

TABLE XI.—*Normal monthly and annual precipitation*—Continued.

DRAINAGE TO THE ATLANTIC OCEAN—*Continued.*

Stations.	Latitude. °	Latitude. ′	Longitude. °	Longitude. ′	Years of record.	Precipitation in inches. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Baltimore, Md	39	18	76	37	25	3.3	3.5	4.1	3.4	3.8	4.0	4.7	4.0	3.9	2.9	3.0	3.0	43.6
Cumberland, Md	39	39	78	45	24	2.1	2.6	2.9	2.5	3.4	3.8	3.4	3.2	2.8	2.3	2.2	2.1	33.3
Boston, Mass	42	21	71	04	79	3.8	3.5	4.1	3.8	3.7	3.2	3.6	4.3	3.4	3.8	4.3	3.9	45.4
New Bedford, Mass	41	39	70	56	83	3.7	3.6	4.0	3.6	3.8	3.0	3.1	3.9	3.3	3.7	4.0	3.8	43.5
Springfield, Mass	42	08	72	35	47	3.5	3.5	3.5	3.2	4.2	3.8	4.5	4.5	3.4	4.2	3.8	3.5	45.6
Concord, N. H	43	12	71	33	42	3.1	2.8	3.1	2.8	3.3	3.1	3.7	3.9	3.4	4.1	3.5	3.0	39.8
Strafford, N. H	43	52	72	25	24	3.4	2.9	3.3	2.5	3.3	3.5	4.1	3.7	3.4	3.1	3.4	3.2	39.8
Atlantic City, N. J	39	22	74	25	22	3.6	3.3	3.8	3.3	3.1	3.0	3.5	4.3	3.2	3.2	3.3	3.5	41.1
New Brunswick, N. J	40	30	74	27	43	3.8	3.6	3.8	3.7	3.9	3.9	4.7	4.9	3.8	3.4	3.7	3.5	46.7
Albany, N. Y	42	39	73	45	69	2.7	2.5	2.8	2.8	3.6	4.1	4.2	4.0	3.5	3.5	3.0	2.7	39.4
New York, N. Y	40	42	74	02	61	3.4	3.4	3.7	3.4	4.0	3.8	4.0	4.7	3.4	3.6	3.7	3.6	44.7
Utica, N. Y	43	05	75	13	40	3.1	2.9	2.9	2.7	3.5	4.3	4.7	3.5	3.5	3.5	3.7	3.4	41.7
Charlotte, N. C	35	13	80	51	18	4.9	4.4	4.5	3.4	4.1	4.5	5.6	5.1	3.5	3.6	3.0	4.0	50.6
Hatteras, N. C	35	15	75	40	21	5.9	4.5	6.1	4.7	4.6	4.6	6.4	6.4	6.4	6.2	5.2	5.5	66.5
Lenoir, N. C	36	00	81	28	25	4.2	4.3	3.9	3.5	4.8	4.1	5.1	5.7	4.6	3.3	3.3	3.6	50.4
Weldon, N. C	36	24	77	30	23	3.8	3.3	4.0	3.4	4.6	4.0	5.1	5.3	4.0	3.8	2.4	3.4	47.1
Wilmington, N. C	34	14	77	57	26	3.8	3.3	3.9	2.9	4.2	5.7	7.1	7.3	6.3	3.8	2.4	3.0	53.7
Dyberry, Pa	41	38	75	18	23	3.0	2.8	3.0	2.5	3.4	3.1	4.6	3.8	2.8	3.3	3.1	2.8	38.2
Grampian Hills, Pa	40	54	78	42	23	3.8	3.6	3.7	3.5	4.4	4.2	4.8	4.1	3.4	2.9	3.0	3.7	45.1
Harrisburg, Pa	40	16	76	53	24	2.8	2.4	2.7	3.0	4.6	4.4	4.2	3.9	3.6	3.3	2.7	2.9	40.5
Philadelphia, Pa	39	57	75	09	72	3.2	3.1	3.4	3.4	3.8	3.8	4.0	4.3	3.5	3.2	3.3	3.3	42.3
Providence, R. I	41	49	71	24	65	4.1	3.8	4.1	3.7	3.8	3.3	3.3	4.2	3.2	3.8	4.2	3.9	45.4
Charleston, S. C	32	47	79	56	89	3.0	2.9	3.5	2.4	3.6	4.8	6.6	7.2	5.7	3.3	2.4	3.1	48.5
Kirkwood, S. C	34	17	80	33	32	3.3	3.2	3.9	3.1	3.6	3.9	5.2	5.3	3.9	2.5	2.5	3.5	43.9
Lunenburg, Vt	44	28	71	41	44	3.0	2.8	3.3	2.6	3.6	3.5	3.9	3.8	3.4	3.5	3.2	2.9	39.5
Birdsnest, Va	37	25	75	52	27	3.8	4.0	5.0	3.7	4.0	3.2	4.7	4.6	3.7	3.8	3.0	3.6	47.1
Lynchburg, Va	37	25	79	09	26	3.8	3.6	3.8	3.3	4.0	3.5	4.1	3.9	3.9	3.2	3.1	2.9	43.1
Norfolk, Va	36	51	76	17	26	3.8	3.8	4.6	4.3	4.2	4.4	5.8	6.3	4.7	3.9	3.1	3.6	52.5
Richmond, Va	37	32	77	25	17	3.3	3.8	3.8	3.8	4.1	3.4	4.8	5.0	3.8	3.4	2.6	3.4	45.2
DRAINAGE TO THE GULF OF MEXICO.																		
Mobile, Ala	30	41	88	02	26	5.1	4.8	7.6	4.6	4.3	5.9	6.7	6.8	5.0	3.4	3.9	4.5	62.6
Montgomery, Ala	32	23	86	18	24	5.4	5.4	6.4	4.8	4.0	4.7	4.6	4.0	2.9	2.3	3.4	4.6	52.5
Cedar Keys, Fla	29	08	83	02	10	3.9	2.9	3.4	2.5	2.3	6.8	8.7	7.7	5.4	2.8	2.5	3.0	51.9
Fort Brook, Fla	28	00	82	28	24	2.5	2.8	3.0	1.9	2.9	7.6	9.8	9.5	6.2	2.4	2.0	2.3	52.9
Key West, Fla	24	33	81	49	49	2.1	1.6	1.6	1.2	2.9	4.5	3.8	5.0	6.6	5.0	2.0	1.9	38.2
Pensacola, Fla	30	25	87	13	16	4.7	3.9	5.5	3.5	3.3	5.4	6.7	8.4	4.8	3.3	3.8	3.9	57.2
Atlanta, Ga	33	45	84	23	33	5.2	5.1	5.7	4.2	3.6	4.1	3.9	4.5	3.7	2.2	3.7	4.5	50.4
Quitman, Ga	30	45	83	50	15	4.9	3.7	5.1	4.0	3.0	6.6	6.2	5.6	4.1	3.8	3.2	3.4	53.6
Columbus, Miss	33	31	88	28	33	5.4	5.8	6.3	5.8	3.6	4.1	4.7	4.2	3.4	2.2	4.6	5.0	55.1
Fort Stanton, N. Mex	33	29	105	38	19	0.6	0.8	1.0	0.6	1.0	1.7	3.2	3.8	2.1	1.4	0.8	1.0	18.0
Santa Fe, N. Mex	35	42	106	01	37	0.6	0.9	0.7	0.7	0.9	1.1	2.7	2.7	1.6	1.1	0.8	0.8	14.6
Austin, Tex	30	17	97	44	30	2.2	2.4	2.5	3.0	4.2	2.7	1.8	2.7	4.2	2.7	2.7	2.3	33.4
Corsicana, Tex	32	04	96	27	17	3.1	2.7	2.8	4.3	5.4	3.3	2.4	1.9	2.6	2.5	3.6	2.9	37.5
El Paso, Tex	31	47	106	30	33	0.4	0.5	0.3	0.1	0.3	0.5	1.6	1.9	1.6	0.8	0.5	0.4	8.9
Fort Concho, Tex	31	22	100	20	15	0.9	1.1	1.0	1.7	3.4	2.5	3.1	2.8	3.0	1.8	1.1	1.4	23.8
Fort Davis, Tex	30	38	103	55	20	0.5	0.4	0.4	0.6	1.0	1.7	3.3	3.8	3.0	1.4	0.5	0.4	17.0
Galveston, Tex	29	18	94	47	26	3.6	3.0	2.9	2.8	3.7	4.9	3.1	5.3	6.0	4.2	4.3	3.9	47.7
Rio Grande City, Tex	26	27	98	47	35	1.1	0.9	0.9	1.2	2.5	2.5	1.4	2.6	3.4	1.9	0.9	1.0	20.3
San Antonio, Tex	29	25	98	25	25	1.7	2.3	2.0	2.5	3.0	3.1	2.0	3.6	3.6	1.8	2.4	2.0	30.0
DRAINAGE TO THE PACIFIC OCEAN.																		
Fort Bayard, N. Mex	32	46	108	30	20	0.7	1.1	0.5	0.4	0.3	0.6	3.2	2.7	1.8	1.1	0.7	0.8	13.9
Fort Wingate, N. Mex	35	29	107	45	30	1.1	1.6	1.0	0.9	0.5	0.6	2.4	2.3	1.3	1.1	0.7	1.0	14.5
Salt Lake City, Utah*	40	46	111	54	29	1.6	1.6	2.1	2.0	2.0	1.1	0.9	1.3	1.0	1.6	1.5	2.0	18.7
DRAINAGE TO THE GREAT LAKES.																		
Chicago, Ill	41	54	87	38	30	2.1	2.2	2.4	3.0	3.7	3.7	3.4	2.9	3.0	2.7	2.7	2.2	34.0
Alpena, Mich	45	05	83	30	23	2.5	2.0	2.0	2.2	3.5	3.7	2.9	3.5	3.8	3.8	2.8	2.5	35.2
Detroit, Mich	42	20	83	03	46	2.0	1.9	2.5	2.6	3.1	3.8	3.6	2.6	3.0	2.6	2.6	2.2	32.5
Grand Haven, Mich	43	05	86	13	25	2.5	2.1	2.3	2.6	3.4	3.8	2.8	2.7	3.6	3.2	3.0	2.6	34.6
Lansing, Mich	42	44	84	26	33	1.8	2.0	2.3	2.4	3.4	4.0	3.1	2.7	2.9	2.5	2.4	2.1	31.6
Marquette, Mich	46	34	87	24	33	2.1	1.9	1.9	2.3	2.9	3.4	2.9	2.9	3.6	3.1	2.8	2.4	32.2
Port Huron, Mich	43	00	82	26	21	2.1	2.4	2.6	2.1	3.4	3.5	2.4	2.6	2.6	2.8	2.8	2.3	31.6
Duluth, Minn	46	47	92	06	26	1.1	1.1	1.6	2.5	3.7	4.5	3.6	3.3	3.7	2.6	1.7	1.3	30.7
Moorhead, Minn.†	46	52	96	44	15	0.7	0.8	0.9	2.2	2.5	4.4	3.9	2.7	2.1	1.9	0.9	0.7	23.7
St. Vincent, Minn.†	48	56	97	14	24	0.5	0.5	0.8	1.5	2.5	3.9	2.6	2.6	1.7	1.8	0.5	0.6	19.5
Buffalo, N. Y	42	53	78	53	26	3.0	2.8	2.6	2.5	3.4	3.5	3.2	3.2	3.3	3.6	3.5	3.4	38.0
Ithaca, N. Y	42	27	76	30	36	2.0	1.9	2.3	2.2	3.4	3.7	3.5	3.0	3.0	2.9	2.6	2.2	32.7
North Hammond, N. Y	44	23	75	45	14	2.9	2.4	2.8	2.1	3.4	2.9	3.6	3.6	3.5	4.1	3.3	2.8	37.4
Oswego, N. Y	43	29	76	35	26	3.0	2.5	2.6	2.1	2.8	3.4	3.1	2.6	2.8	3.3	3.4	3.4	35.0
Plattsburg Barracks, N. Y	44	41	73	26	35	1.7	1.5	2.0	1.8	2.6	3.0	3.4	3.3	2.9	2.8	2.4	2.0	29.4
Rochester, N. Y	43	08	77	42	26	3.1	2.7	2.9	2.5	3.3	3.3	3.0	3.0	2.4	2.9	2.8	2.9	34.8
Cleveland, Ohio	41	30	81	27	41	2.5	2.6	2.7	2.7	3.5	3.9	3.4	3.1	3.6	2.8	3.1	2.7	36.6
Toledo, Ohio	41	40	83	34	25	2.1	2.1	2.1	2.2	3.4	3.4	3.1	2.7	2.4	2.4	2.9	2.4	31.2
Erie, Pa	42	07	80	05	22	3.3	3.4	2.7	2.5	3.8	3.9	2.8	3.3	4.0	4.1	4.1	3.2	41.1
Burlington, Vt	44	28	73	12	53	1.9	1.5	1.8	1.9	3.1	3.2	4.0	3.6	3.5	3.3	2.6	1.9	32.3
Embarrass, Wis	44	25	89	00	28	2.4	2.2	2.5	2.6	3.7	5.3	4.5	4.9	4.1	3.3	2.7	2.6	40.8
Milwaukee, Wis	43	02	87	54	53	1.9	1.6	2.3	2.8	3.4	3.8	3.2	2.7	3.0	2.2	2.2	1.9	31.0

*Drains into Great Salt Lake.

†Drains into Red River of the North.

41. *The isohyetal charts.*—In this table only records covering as much as twenty-five years, for the most part, are used; in some regions of considerable size, however, no lengthy records have been secured, and a few shorter ones are therefore included. These records, erroneous though they be, are, of course, the only source of information as to the true normal precipitation. We, therefore, use them, assuming that their departures from the truth will, in the aggregate, counterbalance each other. The tabular values are laid down on a map of the region covered, and isohyetal lines drawn with due regard to the length of the various records, and the agreement of each with those at surrounding stations. The precipitation chart so constructed is more accurate than the tabular values, and we may, perhaps, assume that the precipitation, as taken from this chart, is correct within 3 per cent. From what has been said, it follows that the normal precipitation at any given point is more likely to be that shown on these charts than that given by an actual gauge record at the station.

42. *Geographical distribution of precipitation.*—The normal precipitation charts are instructive. Noting first the annual distribution of precipitation, as shown on Plate IV, it appears that the eastern slope of the Rocky mountains, as far east as the one hundredth meridian, has a yearly precipitation of less than 20 inches. This region contains the sources of all the western tributaries of the Mississippi. Toward the east and south the precipitation increases, the center of heaviest downpour being near the mouth of the Mississippi, where the annual depth of precipitation slightly exceeds 60 inches. Along the Atlantic coast the precipitation ranges from a little more than 40 inches in the north to something over 50 in the south. Proceeding inland from the coast, the isohyetal lines drop rapidly southward, as the Alleghanies are approached, again bending northward after the mountains are passed.

43. *Seasonal changes in distribution.*—Considering now the monthly charts, we find the heaviest downpour in January, amounting to 6 inches, at the southern extremity of the Alleghanies. During February and March this center of maximum precipitation moves southwest to the Gulf coast near Mobile, Ala. The monthly precipitation at this period is less than 1 inch over most of the Rocky mountain slope and the western plains. During April and May the center of maximum rainfall moves northwest, and the precipitation reaches its greatest value over the West, exceeding that of the winter months by about an inch. In June the rainy season is inaugurated on the Florida peninsula and the Gulf coast, where the monthly downpour is between 6 and 7 inches; at the same time a secondary center of rainfall is found in the lower Missouri valley. In July the rainfall becomes still heavier over Florida, and diminishes in the West. The conditions of August are very similar to those of July, except that the rainfall is more nearly uniform over a large extent of the central Mississippi valley and the Northeast. The latter feature is still more prominent in September, the rainfall being heavy on the immediate coast of the south Atlantic and the gulf of Mexico, while the remainder of the country east of the ninety-fifth meridian has a nearly uniform rainfall of 3 to 4 inches. The same peculiarity is also noticeable in October, as well as a marked diminution of rainfall in the Southeast. In November the winter condition reappears, with light precipitation in the West and the heaviest downpour in the lower valley of the Mississippi. This condition becomes more intense in December, the monthly precipitation exceeding 5 inches in southern Mississippi.

TABLE XII.—*Normal precipitation in river basins.*

Basin.	Subdivision.	Month.												Year.
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	
Ohio.	A	3.3	3.2	3.1	3.0	3.8	4.0	4.0	3.6	3.3	3.2	3.2	3.4	41.1
	B	3.0	3.0	3.1	3.2	3.7	3.9	4.0	3.7	3.4	2.9	2.8	2.9	39.5
	C	3.6	3.4	3.7	3.4	3.7	4.1	4.2	3.6	3.1	2.7	3.1	3.2	41.6
	D	3.8	3.9	4.2	4.0	4.0	4.3	4.1	3.6	2.8	2.7	3.9	3.6	45.0
	E	3.1	3.4	3.8	3.8	4.5	4.6	4.0	3.4	3.0	2.8	3.5	3.2	43.2
	F	4.5	4.5	4.8	4.4	4.0	4.2	4.2	3.6	2.9	2.6	4.0	3.5	47.3
	G	4.8	4.8	4.8	4.4	4.0	4.3	4.5	4.1	3.5	2.8	3.8	3.8	49.6
	Entire basin.	3.8	3.8	4.0	3.8	4.0	4.2	4.2	3.7	3.2	2.8	3.5	3.4	44.2
Upper Mississippi.	A	0.9	0.9	1.4	2.4	3.3	4.2	3.6	3.2	3.1	1.9	1.4	1.1	27.5
	B	1.6	1.5	2.1	2.7	3.7	4.4	3.8	3.3	3.5	2.5	2.0	1.8	32.8
	C	1.5	1.4	2.1	2.9	4.0	4.7	4.2	3.3	3.6	2.6	1.9	1.8	33.7
	D	2.0	2.4	2.7	3.3	4.2	4.3	3.7	3.4	3.2	2.6	2.6	2.2	36.7
	Entire basin.	1.4	1.4	1.8	2.8	3.7	4.4	3.8	3.3	3.3	2.3	1.9	1.6	31.9
Missouri.	A	0.8	0.5	0.6	1.1	2.1	2.8	1.6	1.1	1.0	0.8	0.6	0.6	13.6
	B	0.6	0.5	1.0	1.7	2.6	2.4	1.4	1.1	0.8	0.9	0.6	0.6	14.3
	C	0.7	0.5	1.0	2.1	2.8	3.2	2.0	1.6	0.9	0.9	0.7	0.6	17.0
	D	0.6	0.6	1.3	2.7	3.4	3.6	2.7	2.2	1.4	1.0	0.6	0.6	20.6
	E	0.6	0.7	1.1	2.8	3.3	4.2	3.5	2.7	2.1	1.6	0.8	0.7	24.1
	F	0.6	0.5	1.1	2.2	3.0	2.5	2.2	1.7	1.4	1.1	0.6	0.6	17.3
	G	0.5	0.7	0.9	2.1	3.4	3.5	3.4	2.8	1.8	1.2	0.6	0.6	21.7
	H	1.6	1.9	2.4	3.5	4.6	4.9	4.4	3.6	3.3	2.5	2.0	1.8	36.6
	Entire basin.	0.7	0.7	1.1	2.1	3.0	3.2	2.4	1.9	1.5	1.2	0.8	0.7	19.4
Arkansas.	A	0.6	0.8	1.1	2.0	3.0	2.9	3.0	2.4	1.7	1.3	0.7	1.0	20.4
	B	0.9	1.0	1.1	2.2	3.2	2.8	2.6	2.7	1.8	1.9	1.1	1.1	22.3
	C	1.8	2.1	2.4	3.9	4.6	4.4	3.4	2.9	3.2	3.0	2.4	2.2	36.3
	D	3.6	3.9	4.3	5.0	5.2	4.4	4.3	3.7	3.4	2.8	3.8	3.5	48.0
	Entire basin.	1.6	1.8	2.0	3.0	3.8	3.4	3.2	2.9	2.3	2.1	1.8	1.8	29.6
Red.	A	0.9	0.9	1.1	2.6	4.4	3.4	2.6	3.2	2.3	2.6	1.1	1.3	26.4
	B	4.9	4.8	5.2	5.3	4.9	4.0	4.2	3.4	3.3	3.0	4.9	4.5	52.4
	Entire basin.	2.9	2.8	3.1	3.9	4.6	3.7	3.4	3.3	2.8	2.8	2.9	2.9	39.1
Central Valley.	A	2.6	3.3	3.5	4.2	4.7	4.6	4.0	3.3	3.0	2.6	3.2	2.8	41.9
	B	4.5	4.6	5.1	5.0	4.8	4.6	4.1	3.6	3.4	2.8	4.4	4.0	51.0
	C	4.6	4.6	4.8	4.6	4.2	4.5	3.4	3.2	2.8	2.7	4.5	3.6	47.6
	D	5.6	5.3	6.1	5.8	4.2	4.3	4.3	3.6	3.4	2.5	4.7	4.6	54.5
	E	5.2	5.2	5.9	5.7	4.3	4.6	5.3	4.8	3.6	2.6	4.7	5.1	57.1
	F	5.1	4.5	5.2	5.0	4.6	5.8	6.4	6.0	4.4	3.2	4.8	5.0	60.0
	Entire basin.	4.5	4.5	5.0	5.0	4.5	4.7	4.5	4.0	3.4	2.8	4.5	4.1	51.4
Entire Mississippi basin		1.8	1.8	2.2	2.9	3.6	3.7	3.2	2.7	2.3	1.9	1.9	1.8	29.8

NOTE.—It will be noted that the sum of the 12 monthly values for some districts in the above table does not agree exactly with the annual value. This arises from the fact that the latter has been computed from the annual values of Table XI by the same process by which each monthly value has been computed from the corresponding monthly values of that table.

NORMAL PRECIPITATION ON THE WATERSHEDS.

44. *Method of its computation.*—The logical process for finding the average precipi-

tation over any watershed would be by planimetric measurements from the precipitation charts. Very nearly the same results, however, can be more easily obtained by determining the average precipitation over each of the small divisions, into which the whole Mississippi basin has been divided on the drainage map, Plate I, by a combination of the stations in and about the region considered. In the tables which were given in Section I, the ratio of the area of each of these small divisions to the larger basin of which it is a part has been given. If the precipitation over each small division be multiplied by this ratio and the various products added together, the result will be the average precipitation for the entire basin. By this process the error resulting from an unequal distribution of stations is almost wholly avoided, and the only faulty part of the procedure lies in the fact that the precipitation may be inaccurately determined for some of the small divisions. Following the method outlined above, we deduce the values of normal precipitation on the various watersheds, which are set forth in Table XII. It is not deemed necessary to give in detail the various combinations of stations from which the precipitation over the various drainage areas is determined. The station records have already been given in full in Table XI, and anyone can readily test the accuracy of the computation in any case.

45. *Average precipitation on the various watersheds.*—It is seen, from an examination of the above table, that the Missouri basin receives the least downpour, 19.4 inches, in the year, and the Central Valley the greatest, 51.4 inches, amongst the six grand divisions of the Mississippi drainage basin. The average precipitation of the whole basin is about 30 inches per annum, being lightest in winter and heaviest about the first of June; the ratio of summer to winter downpour is very closely two to one. As to the distribution of precipitation during the year, the Mississippi basin may be divided into two parts. The southeastern third is marked by a fairly uniform and abundant downpour throughout the year. This section embraces all of the Ohio basin and the Central Valley, the southeastern part of the Upper Mississippi basin, a small part of the lower Missouri basin, and the lower Arkansas and Red basins. The remaining two-thirds of the Mississippi basin has a very deficient precipitation during the four months from November to February, inclusive, followed by a rapidly increasing downpour, until a well defined maximum is attained in May or June. The difference in the amount of summer and winter precipitation over this area is very great, the former being five or six times the latter in some districts.

NORMAL DOWNFALL OF WATER.

46. *Downfall in the six chief divisions of the Mississippi basin.*—Having determined the areas of the component basins and the normal precipitation over each, it is a simple computation to find the corresponding downfall of water. In the following table this is given for the six grand divisions of the Mississippi basin for each month and for the year, as computed from the data of Tables I and XII. The amount of downfall is stated in units of ten millions of cubic yards.

TABLE XIII.—*Normal monthly and annual downfall in river basins.*

[Unit of 10,000,000 cubic yards.]

Basin.	Month.												Year.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Ohio	6,595	6,595	6,942	6,595	6,942	7,289	7,289	6,421	5,554	4,860	6,074	5,901	76,710
Upper Mississippi	1,998	1,998	2,570	3,997	5,282	6,281	5,424	4,711	4,711	3,283	2,712	2,284	45.537
Missouri	3,175	3,175	4,989	9,525	13,608	14.515	10,886	8,618	6,804	5,443	3,629	3,175	87,995
Arkansas	2,565	2,885	3,206	4,809	6,091	5,450	5,130	4,649	3,687	3,366	2,885	2,886	47.449
Red	2,246	2,168	2,401	3,020	3,562	2,865	2,633	2,556	2,168	2,168	2,246	2,246	30,279
Central Valley	2.672	2,672	2,968	2,968	2,672	2.790	2,672	2,375	2,019	1,662	2,672	2,434	30,517
Total	19,251	19,493	23,076	30,914	38,157	39,190	34,034	29,330	24,943	20,782	20,218	18,926	318,487

NOTE.—In this table, as in Table XII, the annual values have been computed from the annual values of the preeeding table, and hence are not, as a rule, exactly equal to the sums of the monthly values. The result secured by this process is slightly more aceurate than by summing the months.

NORMAL DISCHARGE OF THE RIVERS.

47. *Determination of discharge.*—The only accurate method of ascertaining the volume of water which passes a given point on a river, is by the direct measurement of the cross section and velocity of the current. The cross section in square feet, multiplied by the mean velocity in feet, will obviously give the volume of discharge in cubic feet. The velocity, however, varies greatly in different portions of the cross section, this variation following a certain law, which was carefully investigated by Humphreys and Abbot. It is plain that the cross section can be stated in terms of the height of the water surface, that is to say, in terms of the river stage as shown by gauge. The velocity, however, is not capable of similar correlation to the stage of river, but also depends upon the local slope of the water surface. The contention was made by Humphreys and Abbot that in the average of a year, or from beginning to end of a flood, covering both the rising and falling stages of the river, the velocity, as well as the cross section, would bear a fixed relation to the stage, and hence that from the average annual stand of the river, the volume of its discharge could be inferred, after the necessary measurements had been made once for all. Much doubt has been cast upon this proposition by subsequent investigations, and no satisfactory connection between the stage and the discharge has been determined as yet.

48. *Available data.*—A great deal of work has been expended on discharge measurements since the initiative by Humphreys and Abbot, but, so far as ascertained, no full discussion has been made of the various series of observations, and the normal discharges of the component basins remain to-day largely a subject of conjecture and estimate. Humphreys and Abbot, by actual daily measurements for a year, determined the discharge of the Mississippi both above the mouth of the Red and below the effluent bayous. By a comparison of the simultaneous gauge readings, made during the year, with the discharge measurements, the average relation of stage and discharge was determined. Then, from a long series of gauge readings made at the same points, the normal discharge of the river was computed and found *to be practically the same above the mouth of the Red and below the outlet bayous.* From this it appears that the discharge of the Red was equivalent to that of the bayous. The discharge of the latter was also measured. One of these outlet bayous, the Plaquemine, has since been closed, and hence the discharge of the Mississippi at its mouth, as determined at that time, should now be increased by the former discharge of bayou Plaquemine. The discharge of the Arkansas was also subjected to direct measurement by Humphreys and Abbot.

From a consideration of the rainfall in connection with discharge measurements made on the Upper Mississippi, above St. Paul, and a comparison of the character of this portion with the remainder of the Upper Mississippi basin, Mr. Jas. L. Greenleaf, of the Mississippi River Commission, has estimated * that in this basin 27.5 per cent of the downfall is discharged.

49. *Computation of normal discharge.*—The data above enumerated forms the basis from which to estimate the normal discharge of the six grand divisions of the Mississippi basin. We have by direct determinations of more or less accuracy the discharge of the Mississippi at its mouth, of the Red and Arkansas rivers, and outlet bayous. The total discharge from the basin will be that of the Mississippi proper, increased by that of bayous Atchafalaya and La Fourche. From the known discharge and downfall of the Arkansas basin we find their ratio to be 0.156. Humphreys and Abbot, and also Greenleaf, assumed, from their physical similarity, that the ratio of discharge to downfall would be the same in the Arkansas and Missouri basins. The latter is decidedly the drier, and it is reasonable to suppose that the ratio will be rather less than greater. We may, perhaps, assume the discharge to be 15 per cent of the downfall, which is the value employed by Humphreys and Abbot. Adopting Greanleaf's estimate of 0.275 as the ratio for the Upper Mississippi, and 0.300 for the Ohio basin, we can compute, from the downfalls given in Table XIII, the discharge from each of the six divisions, except the Central Valley. As the total discharge from the basin is known, we readily compute that of the Central Valley by simple subtraction. Pursuing this method we obtain the data of the following table:

TABLE XIV.—*Normal annual discharge from river basins.*

Basin.	Annual discharge in cubic yards.	Ratio of discharge to downfall.
Ohio	230, 130, 000, 000	0. 300
Upper Mississippi	125, 230, 000, 000	0. 275
Missouri	131, 990, 000, 000	0. 150
Arkansas	74. 070, 000, 000	0. 156
Red	66, 670, 000, 000	0. 220
Central Valley	157, 100, 000, 000	0. 515
Mississippi above the Red	718, 520, 000, 000	....
Mississippi at its mouth	724, 360, 000, 000	....
Bayous Atchafalaya and La Fourche	60, 830, 000, 000	....
Total discharge from Mississippi basin	785, 190, 000, 000	0. 247

50. *Remarks upon the computed discharges.*—The process followed in computing this table differs from that pursued by Humphreys and Abbot, and the results differ essentially. It was assumed by those investigators that the discharge in the districts which we have included under the designation of Central Valley, was 90 per cent of the downfall, but, as pointed out by Greenleaf, there is reason for thinking this too high. Their method, indeed, was to assign first the discharge for all the basins except the Ohio and Upper Mississippi and, assuming the ratio of discharge to downfall the same in each of the latter, to divide the residual discharge between them. Subsequent investigations, however, have established the ratio of discharge to downfall in these basins

* Section on Hydrology in Report on the Water Power of the Mississippi river, Tenth Census.

more accurately than in the Central Valley, and the process followed here has been to first assign the discharge of basins other than the Central Valley, leaving the residual to that region. This leads to the conclusion that the discharge in the latter section is about 52 per cent of the downfall. The Central Valley includes about 30,000 square miles of swamp land and 39,000 square miles of upland; the ratio over the former is doubtless much greater and over the latter much less than this average.

51. *Differences in normal drainage.*—Assuming, as we probably may, that the figures of Table XIV fairly represent the annual discharges from the various basins, we see that the Ohio basin and the Central Valley, together, furnish nearly one-half of the total discharge of the Mississippi, although in area they form but 22 per cent of its basin. The discharge from each of these drainage areas largely exceeds that from the great Missouri basin. It is obvious that the size of a river basin does not measure its hydrological importance; in addition to its size, must be considered the *downpour of rain* over it and the *ratio of its discharge to downfall.* Of the downfall of water over the Mississippi drainage basin there is discharged to the sea, on an average, 25 per cent; the remaining 75 per cent must be ultimately returned to the clouds, although a considerable part is first incorporated into vegetable growth. The relation is seen to be a very variable one in different localities, and doubtless also varies with the season. Under conditions of great aridity the drainage will be *nil*, and under those of the highest humidity may probably reach 95 per cent of the downfall over a considerable region.

NORMAL RIVER STAGES.

52. *Measurement of the stage of a river.*—By the stage of a river is meant simply the height of the water surface at a given point above (or below) a fixed plane of reference. There is no natural plane of reference, unless that corresponding to the normal annual stage might be so considered. In point of fact, the plane of reference is an arbitrary one, selected as accurately as may be at the level of lowest known water. In few cases does the reference plane coincide with the level of extreme low water with close accuracy. Having selected the plane of reference, the vertical distance in feet and tenths of a foot above this plane is indicated on a vertical or slanting surface washed by the river, or, in some instances, the relation of water surface to plane of reference is determined by measuring from an elevated point upon a bridge to the river surface, the height of the bridge above the reference plane being known.

53. *Value of river stage measurements.*—Although, as already pointed out, it is impossible at the present time to deduce the flow of water past the station from the stage of the river, yet the stage in itself is of value. It indicates the danger of overflow in the adjacent portion of the river. The stage at which injury begins depends, of course, on the character of the banks and adjacent lands. The corresponding height on the river gauge is called the danger line. Indeed, it is obvious that the danger at a given place arises directly from the height of a river, without regard to the volume of its flow. The stage may, therefore, be itself made a subject of study, and may be regarded as an index to the state of the river, all important in the immediate locality, and somewhat less important than the discharge for lower points on the river. The record of river stages is happily of considerable extent, covering more than a quarter of a century at many stations, and affords the means of computing normal values throughout the year at several points on the Mississippi and its tributaries.

54. *Stations selected for study.*—Eleven stations have been selected, and normal data computed for them, the latter taken chiefly from the published stages of the Mississippi River Commission. On the Mississippi, Keokuk is taken to represent the regimen of the Upper Mississippi; the lower river is represented by St. Louis below the mouth of the Missouri, Cairo at the mouth of the Ohio, Memphis at the head of the Yazoo bottom, Vicksburg below the confluence of the Arkansas and at the mouth of the Yazoo, and Carrollton, a suburb of New Orleans, below all the tributaries and the outlet bayous. The Tennessee, which is the chief tributary of the Ohio, enters the latter so near its mouth that any station below it will be affected by very high water in the Mississippi at Cairo; and, hence, Cincinnati, on the Ohio, and Johnsonville, on the Tennessee, are both taken to represent the conditions in the Ohio basin. The regimen of the Missouri is well shown by the observations at Hermann. On the Arkansas, Little Rock is selected, and on the Red, Shreveport.

55. *Method of computing normals.*—The daily gauge readings at these stations have been first added in pentads from the first day of each month, the incomplete pentad in February being summed by itself, and the last six days of the months of 31 days being combined. The resultant sums have been obtained for these periods throughout the whole series of years in the record, and then divided by the corresponding number of days included. Any given quotient is taken as the normal stage for the middle of the period covered. The normal stages, as first obtained, are referred to the arbitrary zero planes of the various gauges. Corrections are finally applied to each station record in order to reduce its stages to the plane of lowest known water. The values, so corrected, and plotted on cross-section paper, give the normal hydrographs of Plate III.

56. *Normal regimen of the rivers.*—An examination of these hydrographs discloses in the Upper Mississippi, at Keokuk, a single swell in the year, reaching its height about May 9, and then falling steadily to the latter part of August. From the latter date to the end of January, a period of more than five months, the river is at practically the same low level. The annual rise then begins, continuing to the May crest.

In the Missouri, at Hermann, a swell appears after the minimum, which occurs about December 20, and obtains a minor maximum toward the end of April. The river then falls slightly to the middle of May, after which it rises rapidly to its highest point about June 29. From the June maximum to the December minimum there is a continuous fall, most rapid at first.

The Mississippi below the mouth of the Missouri, at St. Louis, shows the effect of the earlier rise in the Upper Mississippi, and the later one in the Missouri, by a much longer period of high water, with two crests. The river is at a low stage from early in September to the end of January, while the lowest water occurs in the middle of December. From the beginning of February to the end of April the river rises rapidly. This high water lasts to the middle of May, and is succeeded by a slight fall and a subsequent second rise to a high stage during the latter half of June; the river is thus in flood for over two months. From the first week in July there is a steady and rapid fall to the low water of September.

The regimen of the Ohio is shown by the hydrographs for the main stream at Cincinnati, and the Tennessee at Johnsonville. These curves are much more irregular than those already considered, a fact probably due to the disturbing effect of the great floods of this region, for the record at Cincinnati is the longest we have, thirty-nine years. There is seen to be a single annual oscillation, upon which, in our curves, are superim-

posed many small fluctuations, probably adventitious. The lowest stage is reached two months earlier than in the Missouri river, and about the middle of October. By the first of November a sharp rise sets in, and continues to the latter part of January without interruption. There is then a slight falling off, the rise being resumed at the beginning of February. On our hydrographs the highest stage is reached on February 20 at Cincinnati, and on March 24 at Johnsonville, but the curves, as already remarked, are irregular, and probably the normal maximum occurs about March 10. The water remains high to the middle of April, after which a rapid fall sets in and, by the first of August, very low stages are reached.

The early rise of the Ohio, and those following later in the upper Mississippi and Missouri, produces in the Mississippi at Cairo a main swell, which reaches its height about April 15. This is preceded by a slight rise at the end of February, perhaps due to the melting snow, and its decline is checked during June by the Missouri rise. Except for the stationary stage during June, the fall is steady from the highest stage on April 15 to the lowest on October 20, occupying almost exactly six months. The reversal of its course is sudden, and it moves steadily upward from October 20 to April 15, following the regimen of the Ohio. The stages at Memphis are a duplication of those at Cairo, except that the curve is smoother and its maximum and minimum are found about four days later. The retardation in the fall of the river during June is much less marked.

In the hydrographs of the Arkansas river, at Little Rock, we have another curve of great irregularity, the reason for which is not clear. The river is seen to be practically at its lowest stage from the middle of August to the middle of November. A gradual swell then commences, and attains its maximum about May 4. For a month the river remains at nearly the same stage, and then declines slowly to its autumn minimum, the annual range being about 8 feet.

Little effect is produced on the Mississippi by the normal discharge of the Arkansas. The hydrograph at Vicksburg closely resembles that at Memphis, but is much more smooth in its sweep. Its single annual maximum is attained about April 30, and from that time a steady fall takes place until October 29. The stationary period, observed in June at Cairo and Memphis, is barely apparent, as a slight flexure in the curve. The annual range is about 35 feet.

The regimen of the Red river, as shown by the hydrograph at Shreveport, is similar to that of the Arkansas, the highest stage occurring about May 18, and the lowest about September 26. The annual range, however, is much greater. Its discharge apparently produces no effect on the Mississippi. At Carrollton, within 116 miles of its mouth, the annual oscillation of the Mississippi is a long, steady rise of six months' duration and a corresponding fall. The June rise is here apparent only as a slight diminution in the rate of fall.

57. *Mean and extreme river stages.*—The date and height of mean high and low water are most accurately obtained from the charted hydrographs, and their difference gives the mean annual range of the river. From the original records are computed the mean annual stage, and from the same source we obtain the date and stage of highest and lowest known water. When the river stages are referred to lowest water, the highest water necessarily indicates the absolute range in river height. The above data, together with the length of record and established height of danger line, are given in the following table for our eleven selected stations:

TABLE XV.—*Normal and extreme river stages, referred to the plane of lowest water.*

Station.	River.	Length of record.	Mean high water.		Mean low water.		Mean stage.	Mean annual range.	Date of lowest water.	Highest water.		Height of danger line.	
			Date.	Stage.	Date.	Stage.				Date.	Stage.	Above extreme low water.	Above zero of present gauge.
		Years.		*Feet.*		*Feet.*	*Feet.*	*Feet.*			*Feet.*	*Feet.*	*Feet.*
St. Louis, Mo......	Lower Mississippi.	36	June 30	20.9	Dec. 9	7.1*	13.3	13.8	Jan. 27, 1895....	June 28, 1844....	42.1	30.7	30
Cairo, Ill	....do	26	Apr. 15	36.9	Oct. 30	8.0	22.2	28.9	Dec. 24, 1871....	Feb. 27, 1883....	53.2	41.0	40
Memphis, Tenn....	....do	26	Apr. 19	30.4	Oct. 23	6.7	18.1	23.7	Nov. 9, 1895....	Mar. 19–21, 1897.	39.8	35.7	33
Vicksburg, Miss..	....do	24	Apr. 30	46.3	Oct. 27	11.6	29.4	34.7	Nov. 13–14, 1895.	Apr. 16, 1897....	58.6	47.3	41
Carrollton, La......	....do	25	Apr. 28	13.9	Oct. 29	2.8	8.1	11.1	Dec. 27, 1872....	May 7–14, 1897..	20.6	14.6	13
Johnsonville, Tenn.	Tennessee	18	Mar. 24	21.1	Oct. 18	2.4	9.3	18.7	Oct. 20–21, 1876.	Mar. 24, 1897....	48.1	21.1	21
Cincinnati, Ohio ...	Ohio	39	Feb. 20	30.7	Oct. 12	5.4†	15.4	25.3	Sept. 18, 1881....	Feb. 14, 1884....	69.2	43.1	45
Keokuk, Iowa	Upper Mississippi.	27	May 9	12.2	Dec. 5	4.3	7.0	7.8	Nov. 30, 1893....	June 6, 1851	22.9	15.9	14
Hermann, Mo......	Missouri.........	22	June 29	17.4	Dec. 20	6.1	10.9	11.3	Dec. 21–22, 1878.	June 23, 1883....	29.5	25.1	21
Little Rock, Ark...	Arkansas	25	May 4	13.8	Oct. 15	5.6‡	9.3	8.2	Oct. 23–24, 1879.	May 21, 1892....	32.2	24.0	23
Shreveport, La.....	Red	24	May 18	25.7	Sept. 26	9.4	17.8	16.3	Dec. 2–4, 1894...	May 28, 1892....	41.2	34.5	29

* The same stage practically continues to December 23.

† The same stage is reached on September 9 and October 24.

‡ Almost the same stage continues to November 5.

From the pentad means already computed, we readily deduce the normal monthly river stages of the following table, which may prove of utility:

TABLE XVI.—*Normal monthly river stages, referred to the plane of lowest water.*

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
St. Louis, Mo.	8.8	10.5	14.6	19.3	20.2	20.2	18.5	12.7	9.9	9.1	8.8	7.2
Cairo, Ill.	23.3	30.7	34.2	36.0	29.8	26.2	23.0	15.1	11.1	8.7	12.3	15.9
Memphis, Tenn.	18.6	23.8	27.5	29.5	25.4	21.7	19.2	12.9	9.3	7.3	9.3	12.4
Vicksburg, Miss.	27.6	36.4	42.4	45.4	43.3	37.9	33.5	23.0	16.0	12.9	14.6	19.3
Carrollton, La.	6.5	10.3	12.4	13.7	13.2	11.4	9.2	5.5	3.9	3.2	3.2	4.6
Johnsonville, Tenn.	13.9	18.5	19.5	17.7	9.0	6.7	4.7	3.5	3.7	2.7	4.4	6.9
Cincinnati, Ohio.	21.7	26.3	26.5	25.0	18.0	12.4	9.0	7.5	6.5	6.0	10.3	15.9
Keokuk, Iowa.	5.8	5.6	7.7	10.4	11.5	9.9	8.1	5.0	5.1	5.4	4.9	4.7
Hermann, Mo.	7.7	9.5	11.1	14.0	13.9	16.2	15.5	11.7	9.4	7.7	7.4	6.6
Little Rock, Ark.	9.1	11.2	11.6	11.7	13.2	11.8	9.4	7.3	6.3	6.0	6.3	7.7
Shreveport, La.	19.0	22.2	24.4	23.7	24.5	22.0	17.5	13.0	9.9	10.1	11.9	14.9

SECTION III.

THE RIVER IN FLOOD.

Constant liability to flood in the alluvial regions.—Notable floods.—Floods since 1870.—Frequency and duration of floods.—Chief floods of the past quarter-century.—Six floods selected for study.—Precipitation in the six floods.—Downfall in the six floods.—Flood of 1882: Its two swells.—The downfall which caused it.—Origin of the flood.—Flood of 1883: Its single great rise.—The accompanying precipitation.—Flood of 1884: Its main features.—Distribution of rainfall.—Flood of 1890: The rise in three swells.—Origin of the flood.—Flood of 1893: A summer flood.—The source of it.—Flood of 1897: Its chief features.—The rainfall and probable drainage.—Source of the flood.—Relative importance of these six floods.—Cause of Mississippi floods.

AS the greater and more fertile portion of the lands bordering the Mississippi from Cape Girardeau to the Gulf are below the high-water level of the river, the history of damage from the overflow of the Mississippi begins with the first settlement of the valley. The first permanent establishment of Europeans on the Lower Mississippi was at Natchez and New Orleans. The former town was built on the bluff above danger of flood, but the initial plans for New Orleans, in 1717, provided for a levee in front of it. Ever since that time there has been a constant struggle to keep back the floods of the river from the towns and plantations along its banks. Nearly every year some portion of the valley is inundated, but the notable floods occur at longer intervals. The great floods of the past were made a special subject of inquiry by Humphreys and Abbot, who collected data for all known floods up to that of 1859. The record has been continued to 1874 by Abbot in the report of the special commission of engineers, authorized by Congress in 1874, "to investigate and report a permanent plan for the reclamation of the alluvial basin of the Mississippi river subject to inundation." Since that time the stage of river has been recorded daily at many points.

FLOODS OF THIS CENTURY.

58. *Notable floods.*—Prior to 1798 little is known, except by tradition, as to the occurrence of floods. The notable floods of this century up to 1870 are those of 1815, 1828, 1844, 1849, 1850, 1851, 1858, 1859, 1862, 1865, and 1867. Of floods subsequent to that of 1867 there are abundant gauge readings; the years in which notable floods occurred during this time are 1874, 1882, 1884, 1890, 1893, and 1897. The flood of 1858 was made the subject of careful measurement by the Delta Survey, and has served ever since as the standard of comparison. It was long thought to represent the full possibility of danger from flood, but its high-water marks were far exceeded by the flood of the present year. A comparative table of flood heights for the notable floods from 1828 was worked out by Humphreys and Abbot, and was subsequently brought down to 1874 by Abbot, in the report referred to above. In the following table this comparison

has been extended to include the flood of this year. The plane of reference is the flood level of 1858. A plus sign indicates that the flood in question exceeded that of 1858, and a minus sign that it fell short of this height.

TABLE XVII.—*Flood heights for great floods from 1828, referred to the flood level of 1858.*

Station.	1828.	1844.	1849.	1850.	1851.	1858.	1859.	1862.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Cairo, Ill.	......	......	......	......	......	0.0	−3.1	+1.2
Memphis, Tenn	−1.3	−1.0	−3.3	−0.6	−1.0	0.0	−0.1	+0.5
Helena, Ark.	−1.5	−2.4	−1.8	−1.8	−4.8	0.0	−1.0	+1.8
Vicksburg, Miss.	−0.6	−0.8	−0.6	+0.1	....	0.0	+1.3	+2.2
Natchez, Miss	+0.7	+0.1	−0.3	−0.5	−0.7	0.0	+1.2	+2.1
Baton Rouge, La	+0.2	−0.6	+0.4	0.0	0.0	0.0	+0.5	+1.3
Carrollton, La	+0.1	−0.6	+0.1	−1.3	+0.3	0.0	+0.4	+0.8
Station.	**1865.**	**1867.**	**1874.**	**1882.**	**1884.**	**1890.**	**1893.**	**1897.**
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Cairo, Ill.	−1.6	+0.9	−2.2	+2.3	+2.2	−0.8	−0.3	+2.0
Memphis, Tenn.	−0.6	0.0	−0.3	+0.9	−0.1	+1.3	+0.9	+2.8
Helena, Ark.	−0.2	+1.2	+1.2	+2.6	+2.4	+3.1	−3.3	+7.2
Vicksburg, Miss.	−0.5	−0.1	−3.2	−0.1	+0.1	+0.1	+0.6	+3.4
Natchez, Miss	....	−0.3	−2.6	−0.4	−0.8	+0.4	−1.4	+2.8
Baton Rouge, La.	....	....	+1.5	+1.3	+1.4	+1.9	+3.7	+5.9
Carrollton, La.	....	....	+1.0	0.0	+0.6	+1.0	+2.4	+4.0

59. *Floods since 1870.*—The establishment of numerous permanent river gauges in 1871 has greatly facilitated a study of the floods since that time. In Table XVIII, the highest and flood waters of each year from 1872 to 1897, inclusive, are given, with their dates and duration. The later feature is set forth in the number of days the river was above the danger line of the gauge. The five stations, St. Louis, Cairo, Memphis, Vicksburg, and Carrollton are selected, as well typifying the different sections of the Lower Mississippi river. As has been done in the previous tables of Section II, the river stages are here referred to the plane of lowest water. Whenever more than one period of flood occurs in the same year, the highest water of each flood is given.

TABLE XVIII.—*Floods and highest waters in the Lower Mississippi for each year from 1872 to 1897, inclusive.*

[Stages referred to the plane of lowest water.]

ST. LOUIS, MO.

Year.	Highest stage.	Date.	River above danger line.		
			From—	To—	Number of days.
	Feet.				
1872	23.7	June 12–14	....	....	....
1873	26.1	Apr. 11	....	....	....
1874	19.1	June 19, 20	....	....	....
1875	30.5	Aug. 3	....	....	....
1876	32.7	May 10	May 9	May 14	6
1877	27.3	June 14	....	....	....
1878	26.5	June 15	....	....	....
1879	21.9	July 3	....	....	....
1880	26.2	July 2	....	....	....
1881	34.3	May 6	Apr. 27	May 8	12
1882	33.1	July 5	July 2	July 10	9
1883	35.5	June 26	June 17	July 3	17

TABLE XVIII.—*Floods and highest waters in the Lower Mississippi*—Continued.

ST. LOUIS, MO.—*Continued.*

Year.	Highest stage.	Date.	River above danger line. From—	To—	Number of days.
	Feet.				
1884	28.8	Apr. 9, 10			
1885	27.8	June 17			
1886	27.7	May 13			
1887	21.4	Apr. 3			
1888	30.1	June 4			
1889	25.3	June 1			
1890	21.3	July 1			
1891	24.4	July 4			
1892	36.7	May 19	May 12	June 16	35
	31.8	July 9	July 4	July 15	12
1893	32.3	May 3	May 1	May 5	5
1894	24.1	May 11			
1895	17.8	July 8			
1896	28.4	May 26, 28			
1897	31.7	May 2	May 1	May 5	5

CAIRO, ILL.

Year.	Highest stage.	Date.	From—	To—	Number of days.
1872	40.2	Apr. 19, 20			
1873	42.6	Feb. 26	Feb. 22	Mar. 2	9
	41.6	Apr. 12	Apr. 10	Apr. 14	5
1874	45.0	Mar. 11	Feb. 27	Mar. 15	17
	48.4	Apr. 26	Apr. 16	May 13	28
1875	44.7	Mar. 21	Mar. 9	Apr. 9	32
	46.1	Aug. 8	July 20	Aug. 18	30
1876	46.2	Feb. 5	Jan. 29	Feb. 24	27
	47.4	Apr. 6, 7	Mar. 23	May 18	57
1877	41.5	Apr. 15	Apr. 14	Apr. 16	3
1878	38.0	Apr. 29			
1879	37.5	Dec. 31			
1880	42.8	Jan. 15, 16	Jan. 12	Jan. 19	8
	45.6	Mar. 22	Feb. 20	Mar. 30	40
1881	43.4	Feb. 25	Feb. 20	Mar. 2	11
	46.8	Apr. 20	Apr. 14	May 12	29
1882	52.9	Feb. 26	Jan. 14	Apr. 4	81
	43.5	May 23	May 13	June 11	30
1883	53.2	Feb. 27	Feb. 14	Mar. 12	27
	45.2	Apr. 15	Apr. 8	May 4	27
1884	52.8	Feb. 22–24	Feb. 7	Apr. 11	65
1885	40.0	Jan. 26			
1886	52.0	Apr. 19	Apr. 2	Apr. 27	26
1887	49.5	Mar. 9, 10	Feb. 7	Mar. 22	44
1888	46.4	Apr. 4	Mar. 29	Apr. 18	21
1889	35.5	June 24			
1890	44.7	Jan. 20, 21	Jan. 16	Jan. 31	16
	49.8	Mar. 12	Feb. 13	Apr. 14	61
1891	47.2	Mar. 3–6	Feb. 13	Apr. 19	66
1892	49.3	Apr. 28	Apr. 6	June 18	74
1893	45.9	Feb. 28	Feb. 20	Mar. 4	13
	50.3	May 8, 10	Apr. 17	June 14	59
1894	38.0	Feb. 16			
1895	34.3	Mar. 25			
1896	40.1	Apr. 13			
1897	52.6	Mar. 25, 28	Feb. 28	Apr. 27	59

MEMPHIS, TENN.

Year.	Highest stage.	Date.	From—	To—	Number of days.
1872	34.2	Apr. 24			
1873	35.2	Mar. 3			
1874	36.7	May 2	Mar. 9	May 15	68
1875	35.7	Aug. 15–17	Aug. 14	Aug. 18	5
1876	36.8	Apr. 8, 9	Mar. 30	Apr. 19	21
1877	34.7	Apr. 29			

TABLE XVIII.—*Floods and highest waters in the Lower Mississippi*—Continued.

MEMPHIS, TENN.—*Continued.*

Year.	Highest stage.	Date.	River above danger line. From—	To—	Number of days.
	Feet.				
1878	31.8	May 2			
1879	30.8	Jan. 29			
1880	36.1	Mar. 24–29	Mar. 18	Mar. 31	14
1881	36.0	Apr. 27, 28	Apr. 25	May 2	8
1882	37.9	Mar. 6–9	Jan. 25	Mar. 30	65
1883	37.5	Mar. 6–8	Feb. 21	Mar. 15	23
1884	36.9	Mar. 1–3	Feb. 17	Apr. 9	53
1885	31.9	Jan. 28			
1886	37.5	Apr. 28	Apr. 13	May 1	19
1887	38.0	Mar. 10	Feb. 16	Mar. 26	39
1888	36.9	Apr. 11, 12	Apr. 6	Apr. 18	13
1889	29.3	June 27			
1890	36.0	Jan. 27, 31	Jan. 25	Feb. 2	9
	38.3	Mar. 16, 17, 23–25			
		Apr. 4, 5	Mar. 5	Apr. 19	46
1891	37.6	Mar. 10	Feb. 26	Apr. 21	55
1892	37.3	May 2, 3	Apr. 14	June 20	68
1893	37.9	May 15–17	May 1	June 16	47
1894	31.7	Feb. 19, 20			
1895	26.7	Jan. 24, 25; Mar. 29			
1896	32.1	Apr. 15, 16			
1897	39.8	Mar. 19–21	Mar. 10	May 1	53

VICKSBURG, MISS.

Year.	Highest stage.	Date.	From—	To—	Number of days.
1872	45.8	May 2, 3			
1873	46.9	May 29, 30			
1874	52.0	May 2–5	Mar. 14	June 4	83
1875	49.3	Apr. 21	Mar. 29	May 3	36
1876	51.2	May 10	Feb. 10	June 13	125
1877	47.9	May 8–13	Apr. 29	May 26	28
1878	47.3	Mar. 24–27	Mar. 24	Mar. 27	4
1879	45.7	Feb. 17			
1880	49.5	Apr. 8, 9	Mar. 11	May 3	54
1881	48.1	Mar. 10, 12	Mar. 2	May 22	82
1882	55.1	Mar. 20, 21	Jan. 22	July 2	162
1883	50.1	Apr. 7	Feb. 24	May 17	83
1884	55.3	Mar. 25	Feb. 16	June 1	107
1885	48.7	Feb. 3	Jan. 21	Feb. 7	18
1886	50.5	May 7–9	Apr. 18	June 4	48
1887	51.0	Mar. 26–31	Feb. 25	Apr. 10	45
1888	50.5	Apr. 26	Apr. 13	May 5	23
1889	40.7	July 3			
1890	55.3	Apr. 24, 25	Jan. 30	June 4	126
1891	54.4	Apr. 2–4	Feb. 21	May 14	83
1892	54.7	June 2–4	Apr. 14	July 24	102
1893	48.7	Mar. 13–15	Mar. 8	Mar. 21	14
	54.6	May 22, 23	May 1	July 1	62
1894	47.2	Apr. 2			
1895	38.0	Apr. 4			
1896	45.3	Apr. 21			
1897	58.6	Apr. 16	Mar. 16	June 3	80

CARROLLTON, LA.

Year.	Highest stage.	Date.	From—	To—	Number of days.
1872	13.9	May 6			
1873	14.5	June 3, 4			
1874	17.6	Apr. 15	Mar. 17	May 18	63
1875	12.9	May 3–5, 14, 16, 18			
1876	14.3	May 11			
1877	12.7	June 4, 8			
1878	12.9	Mar. 21			
1879	12.4	Feb. 20, 22			

TABLE XVIII.—*Floods and highest waters in the Lower Mississippi*—Continued.

CARROLLTON, LA.—*Continued.*

Year.	Highest stage.	Date.	River above danger line.		
			From—	To—	Number of days.
	Feet.				
1880	15.8	Apr. 23, 24	Mar. 22	May 21	61
1881	14.2	Apr. 12	....	....	....
1882	16.6	Mar. 27	Feb. 11	May 12	91
1883	17.0	Apr. 7	Mar. 17	June 16	92
1884	17.2	Mar. 18	Feb. 24	June 8	106
1885	15.2	Jan. 22, 23	Jan. 22	Feb. 14	24
1886	15.4	May 31	Apr. 27	June 11	46
1887	16.1	Apr. 6–9	Mar. 9	Apr. 19	42
1888	16.0	Apr. 26	Apr. 16	May 11	26
1889	13.2	Mar. 13, 14	....	....	....
1890	17.6	Mar. 14–17, 22	Feb. 3	May 30	117
1891	17.6	Mar. 16	Feb. 20	May 19	89
1892	18.8	June 12, 13	Apr. 14	July 25	103
1893	14.8	Mar. 17	Mar. 15	Mar. 23	9
	19.0	June 22, 24	May 7	July 14	69
1894	15.0	Apr. 5–7	Apr. 1	Apr. 12	12
1895	11.7	Apr. 8	....	....	....
1896	15.3	Apr. 24	Apr. 19	Apr. 27	9
1897	20.6	May 7–14	Mar. 18	June 13	88

60. *Frequency and duration of floods.*—From the above table we perceive that only rarely does the river above Cairo reach a dangerous height, but from Cairo to the Gulf the years without flood water are exceptional. At St. Louis we find, in the twenty-six years covered, only seven in which the river rose above the danger line; and the average number of days the water remained at the flood height, in these seven floods, was fourteen. At Cairo the years of flood number eighteen, with an average duration of flood of fifty-four days; at Memphis we find sixteen flood years, with an average length of flood of thirty-seven days; at Vicksburg, floods, averaging seventy-two days in length, have occurred in nineteen years; at Carrollton the flood years are sixteen in number, and the average duration of flood sixty-five days. As to the season in which floods occur, we find the earliest date on which the river has been above danger line to be: at St. Louis, April 27; at Cairo, January 12; at Memphis, January 25; at Vicksburg, January 21; and at Carrollton, January 22. The latest date to which the flood has continued is: at St. Louis, July 15; at Cairo, August 18; at Memphis, August 18; at Vicksburg, July 24; and at Carrollton, July 25. In the past twenty-six years, therefore, there has been no flood water in any portion of the Lower Mississippi between August 18 and January 12.

61. *Chief floods of the past quarter-century.*—The loss incident to a flood depends not alone on the great height reached by the water, but also on the duration of the dangerous stage. Measured by its destructive character, the first notable flood since 1870 was that of 1874. In that year the river did not reach the height of the 1858 flood at Cairo, but almost attained it at Memphis, and exceeded it at Helena by a foot; at Vicksburg and Natchez the flood was lower by about 3 feet than in 1858, but south of the Red river it was higher by more than a foot.

In 1882 a great flood occurred, the water at Cairo, Memphis, and Helena reaching the highest point recorded up to that time. At Vicksburg and Natchez, the river

closely approached the stage of 1858, but fell short of that of 1862. The record of 1858 was exceeded by 1.3 foot at Baton Rouge, and equaled at Carrollton. The river remained in flood at Cairo for eighty-one days, and at Vicksburg for one hundred and sixty-two days, the longest flood period recorded at either station.

The flood of 1883 was notable only for the great and sudden rise at Cairo to the highest stage ever recorded at that point. At Memphis and Vicksburg, the water did not reach an extreme stage, nor was the flood of unusual duration. The stage at Carrollton exceeded that of the previous year, and the flood was of equal length.

In 1884 about the same stages were reached as in 1882, but the flood was of much shorter duration at Vicksburg and above. At Carrollton the height of the river exceeded that of 1882 by 0.6 foot, and the flood lasted one hundred and six days. In this year the highest water ever known occurred in the Ohio.

The next five years were marked by moderate waters and freedom from serious flood damage. In 1890 another notable flood occurred in the lower river, but was not of marked severity above Memphis.

In 1892 and 1893 there were moderate floods, differing from those previously noted in occurring much later in the year. They may be termed summer rather than spring floods. In 1893 the highest water up to that time was reached at Helena, Baton Rouge, and Carrollton.

In the spring of 1897, a great flood occurred, although not of extreme duration. The river nearly reached the stage of 1883 at Cairo, and from Memphis to its mouth rose to a height greater than ever before recorded. The flood exceeded that of 1858 by 2.0 feet at Cairo, 2.8 at Memphis, 7.2 at Helena, 3.4 at Vicksburg, 2.8 at Natchez, 5.9 at Baton Rouge, and 4.0 at Carrollton.

STUDY OF RECENT FLOODS.

62. *Six floods selected for study.*—Of the floods of the last twenty-six years, those of 1882, 1890, and 1897 are readily distinguishable as the most serious and destructive. These floods, together with that of 1883, in which the maximum height of water was reached at the head of the alluvial plain; that of 1884, during which the Ohio was in greatest flood; and that of 1893, as a type of summer flood, have been subjected to analysis. In determining the sources of a flood in the Lower Mississippi, we will study the gauge records at certain points, so selected as to indicate the contributions of all the chief tributaries, whence a flood may come. The waters from the great Missouri basin and that of the Upper Mississippi must pass St. Louis, and hence the stage at that point will serve as an index to flood waters out of those basins. The stages at Cincinnati and Johnsonville will sufficiently gauge the waters of the Ohio basin; a flood from the Arkansas will be shown on the gauge at Little Rock, and one from the Red on the Shreveport gauge. On the Lower Mississippi itself, the combined effect of the waters from the Ohio, Upper Mississippi, and Missouri is shown at Cairo; at Memphis the same water appears, less that passing into the St. Francis bottom; at Vicksburg, there has been added the drainage from the St. Francis, White, Arkansas, and Yazoo; and at New Orleans the last tributary, the Red, and the effluent bayous have been passed. For the stations enumerated, hydrographs have been constructed from the daily gauge readings, for each of the six floods. These cover, in each flood, a period of four months, embracing the rise, culmination, and decline of the flood. For the first

three months of each period covered by the hydrographs, charts of the actual monthly precipitation have been drawn. It is found that, in each flood, the excessive precipitation, to which the flood was due, occurred within a period of two months, and a chart of the departure from the normal precipitation is given for each of these months, together with a chart showing the total departure in the two months. There are thus six rainfall charts and a sheet of hydrographs for each of the six selected floods.

63. *Precipitation in the six floods.*—By a process similar to that followed in determining the normal precipitation over the various basins, the monthly precipitation during each flood, over the six grand divisions of the Mississippi drainage basin, has been computed, and is presented in the following table:

TABLE XIX.—*Precipitation in six floods.*

Subdivisions.	1882.			1883.			1884.			1890.			1893.			1897.		
	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.	Apr.	May	June	Jan.	Feb.	Mar.
OHIO BASIN.																		
A	5.6	4.0	4.7	3.0	5.8	2.2	4.2	5.6	4.4	4.4	4.8	4.8	4.9	5.6	2.8	2.5	4.0	3.8
B	5.9	4.4	3.9	3.0	4.9	3.2	3.8	5.7	5.5	3.6	5.7	4.6	3.8	5.5	3.6	1.5	6.2	3.9
C	6.7	5.7	4.3	3.1	7.6	3.4	3.7	6.7	4.8	4.8	6.5	6.7	6.2	4.7	4.6	2.3	6.4	6.6
D	4.3	8.2	6.6	3.0	7.9	3.3	3.2	8.0	3.9	5.9	7.8	8.1	6.9	6.0	5.3	3.1	4.8	7.9
E	3.8	6.9	4.6	2.1	7.6	2.2	1.6	5.6	3.7	6.5	5.2	5.4	7.5	4.6	4.7	3.6	2.8	5.9
F	11.1	7.7	7.0	4.1	6.8	3.4	5.2	7.6	7.5	6.2	9.5	7.8	5.9	6.7	5.5	3.2	4.7	8.0
G	12.0	6.9	5.7	5.9	4.8	3.5	5.1	7.5	8.8	4.4	8.1	5.6	4.4	6.7	5.1	3.2	5.5	8.6
Entire basin	7.2	6.3	5.1	3.6	6.3	3.1	3.9	7.0	6.7	5.0	6.9	6.0	5.6	5.7	4.6	2.8	5.0	6.6
UPPER MISSISSIPPI BASIN.																		
A	0.7	1.3	2.4	0.9	0.7	0.3	0.5	1.5	1.2	0.9	0.6	0.8	3.8	2.5	2.1	1.9	1.2	1.8
B	1.0	1.5	3.4	1.4	2.6	0.5	0.9	1.7	2.4	2.1	1.3	1.9	4.5	2.6	4.8	2.9	1.3	2.7
C	0.8	1.5	3.0	1.3	3.3	0.9	0.6	1.5	2.8	2.0	1.0	1.8	5.4	3.9	4.8	3.1	1.0	2.7
D	1.9	4.1	3.9	1.4	5.3	1.1	0.9	2.6	3.0	4.6	2.4	3.5	6.0	3.6	3.7	4.7	1.9	4.6
Entire basin	1.0	1.9	3.0	1.2	2.6	0.6	0.7	1.7	2.2	2.1	1.2	1.8	4.8	3.1	3.7	2.9	1.3	2.7
MISSOURI BASIN.																		
A	0.4	0.3	0.7	1.4	0.5	0.9	0.7	0.5	0.4	0.4	0.5	0.6	1.0	2.7	1.4	0.6	0.9	1.6
B	0.4	0.2	0.4	1.4	0.4	0.9	0.4	0.4	0.9	0.8	0.6	0.9	1.4	2.4	1.1	0.6	0.8	1.7
C	0.2	0.2	0.8	1.7	0.5	1.5	0.3	0.4	1.0	0.5	0.3	1.1	1.5	2.7	2.6	1.0	0.8	1.4
D	0.1	0.1	0.4	1.4	0.5	1.4	0.5	0.8	1.4	0.7	0.6	1.3	3.8	2.6	2.6	1.4	0.4	2.1
E	0.5	0.4	1.1	0.6	0.7	0.6	0.4	1.2	1.8	0.8	0.4	1.0	3.3	2.1	3.9	1.6	0.9	1.5
F	0.4	0.2	0.2	1.3	0.9	0.5	0.5	0.7	2.0	0.6	0.4	0.6	1.4	2.5	2.2	0.5	0.6	1.2
G	0.4	0.3	0.1	0.6	1.1	0.4	0.2	0.9	1.7	0.9	0.3	0.3	0.3	1.8	2.3	1.2	1.3	1.3
H	0.9	3.4	2.3	1.5	3.5	1.6	1.1	2.6	3.2	4.3	1.8	3.1	6.3	5.3	5.6	4.2	1.7	4.3
Entire basin	0.4	0.5	0.7	1.3	0.9	1.2	0.5	0.8	1.5	1.0	0.6	1.0	2.0	2.7	2.5	1.2	0.9	2.2
ARKANSAS BASIN.																		
A	0.7	0.2	0.6	0.4	1.4	0.6	0.4	1.0	1.4	1.0	0.5	0.3	1.7	2.0	1.7	1.1	1.3	2.0
B	0.7	0.9	0.9	0.3	1.6	0.7	0.4	0.7	1.2	1.5	0.8	0.9	1.2	2.2	1.4	2.2	1.0	2.6
C	1.8	3.7	2.3	1.0	3.1	1.2	0.5	3.1	1.4	3.6	1.9	2.6	4.2	5.2	3.9	4.6	1.2	4.5
D	6.7	8.9	4.9	3.3	6.2	2.9	2.8	9.7	4.5	8.2	6.5	6.9	8.7	9.8	5.4	7.2	3.0	9.3
Entire basin	2.2	2.9	1.9	1.1	2.8	1.2	1.0	3.2	2.2	3.1	2.2	2.3	3.5	4.3	2.8	3.3	1.6	4.2
RED BASIN.																		
A	0.6	1.0	1.0	0.2	1.4	1.7	0.4	0.4	1.8	2.0	0.2	0.2	0.3	2.8	1.3	1.7	0.5	1.8
B	8.8	8.0	4.8	5.5	6.8	4.4	5.4	7.3	5.9	7.0	5.4	4.6	4.5	9.6	6.0	7.0	1.5	7.4
Entire basin	4.6	4.4	2.9	2.8	4.0	3.0	2.8	3.8	3.8	4.4	2.8	2.4	2.4	6.1	3.6	4.3	1.0	4.5
CENTRAL VALLEY.																		
A	4.1	9.0	4.4	1.6	6.8	2.2	1.4	5.4	3.1	7.2	4.6	6.0	9.9	5.4	5.2	4.8	2.8	7.2
B	9.0	10.1	6.2	3.5	7.8	3.2	3.9	9.2	5.6	8.0	7.6	7.1	6.1	8.8	8.1	5.1	4.4	9.6
C	9.6	10.0	6.6	3.7	8.4	3.3	4.0	7.6	4.6	7.4	7.8	7.0	6.2	10.0	5.5	4.2	4.6	8.8
D	13.0	8.6	7.4	6.2	6.5	3.4	6.5	9.6	7.8	6.9	7.9	6.5	5.4	11.5	4.5	5.3	4.4	9.4
E	12.7	6.1	6.7	9.0	5.4	4.6	7.6	7.3	8.8	3.0	6.7	6.2	2.9	9.5	5.6	5.6	4.2	6.3
F	4.0	4.6	1.4	12.0	2.6	5.4	7.2	2.4	9.2	1.2	3.0	2.4	6.8	2.7	7.0	3.4	5.0	5.3
Entire basin	8.2	8.2	5.3	5.7	5.2	4.0	4.8	6.8	6.3	5.8	5.1	6.8	6.6	7.8	6.0	4.7	4.2	7.8

64. *Downfall in the six floods.*—A knowledge of the discharges from the component basins and that of the Mississippi itself, during these floods, is greatly to be desired, but such information is not to be had in any completeness. We can, however, from the data of Table XIX, compute the downfall over the various watersheds, and thus obtain some idea of the sources of the different floods. In the following table the departure of the downfall from its normal value is given for the six grand divisions of the entire basin.

TABLE XX.—*Departure from normal downfall in six floods.*

[Unit of 10,000,000 cubic yards.]

River basin.	1882.				1883.				1884.			
	Jan.	Feb.	Mar.	Three months.	Jan.	Feb.	Mar.	Three months.	Jan.	Feb.	Mar.	Three months.
Ohio	+5,901	+4,339	+1,909	+12,149	− 347	+4,339	−1,561	+2,431	+ 173	+5,554	+4,686	+10,413
Upper Mississippi	− 570	+ 714	+1,712	+ 1,856	− 285	+1,713	−1,614	− 186	− 999	+ 429	+ 570	0
Missouri	−1,361	− 907	−1,814	− 4,082	+2,722	+ 907	+ 454	+4,083	− 907	+ 462	+1,815	+ 1,370
Arkansas	+ 962	+1,764	− 160	+ 2,566	− 802	−1,603	−1,282	− 481	− 962	+2,245	+ 320	+ 1,603
Red	+1,316	+1,239	− 155	+ 2,400	− 78	+ 930	− 78	+ 774	− 78	+ 775	+ 542	+ 1,239
Central Valley	−2,196	+2,195	+ 179	+ 4,571	+ 712	+ 415	− 593	+ 534	+ 178	+1,365	+ 772	+ 2,315

River basin.	1890.				1893.				1897.			
	Jan.	Feb.	Mar.	Three months.	April.	May.	June.	Three months.	Jan.	Feb.	Mar.	Three months.
Ohio	+2,083	+5,380	+3,471	+10,934	+3,124	+2,950	+ 694	+6,768	−1,736	+2,083	+4,512	+ 4,859
Upper Mississippi	+1,000	− 285	0	+ 715	+2,855	− 857	− 999	+ 999	+2,142	− 142	+1,284	+ 3,284
Missouri	+1,361	− 454	− 453	+ 454	− 453	−1,361	−3,176	−4,990	+2,268	+ 907	+4,990	+ 8,165
Arkansas	+2,404	+ 642	+ 481	+ 3,527	+ 802	+ 802	− 952	+ 642	+2,725	− 320	+3,517	+ 5,922
Red	+1,161	0	− 512	+ 619	−1,162	+1,162	− 77	− 77	+1,084	−1,394	+1,084	+ 774
Central Valley	+ 771	+ 355	+1,069	+ 2,195	+ 950	+1,959	+ 772	+3,681	+ 118	− 178	+1,673	+ 1,013

FLOOD OF 1882.

65. *Its two swells.*—From an inspection of the hydrographs for the flood of 1882, as shown on Plate XXIII, it is seen that this flood rose at Cairo in two swells, the first culminating on February 3, at a height of 7.6 feet above danger line, and the second on February 26, at 11.9 feet, the river remaining above danger line for eighty-one days. Both swells came chiefly from the Ohio, although the second was slightly increased by the rise shown in the Mississippi at St. Louis. At Memphis the river was in flood from January 25 to March 30, a period of sixty-five days, but only reached a height of 2.2 feet above danger line. At Vicksburg and New Orleans the river rose slowly from the beginning of the year, reaching the danger line at Vicksburg on January 22, and at New Orleans on February 11.* The river was in flood at the latter point for ninety-one days, to May 12; at Vicksburg the river remained above danger line for one hundred and sixty-two days, to July 2. There was a small flood in the Arkansas during the latter part of February, and a great swell in the Red from the middle of January to the middle of April.

66. *The downfall which caused it.*—The precipitation which caused this flood is shown on the monthly precipitation charts, Plates XVII to XIX, and its average amount over the various watersheds has been computed in Table XIX. It is seen that in January the precipitation is heavy in the Ohio basin, the Central Valley, and the lower sections of the Arkansas and Red basins. In February heavy rainfall continued in these sections, becoming still heavier in the lower Arkansas basin, and extended to

* Danger line at New Orleans is taken at 13.5 feet, although danger to the city itself does not begin until a stage of 16 feet is reached.

the southern portions of the Upper Mississippi basin, and a small part of the Missouri basin. In March similar conditions held, with a further increase of rainfall in the Upper Mississippi basin. There is seen, from Table XX, to be a large excess in the downfall over the Ohio basin and Central Valley during January and February, and a smaller excess in March. The downfall in the Arkansas and Red basins was also above the normal in January and February, but slightly deficient in March. In the Missouri basin there was a deficient downfall in each of the three months; in the Upper Mississippi basin the downfall somewhat exceeded the normal in February and March. This distribution of the flood rain is illustrated in the departure charts, Plates XX to XXII.

67. *Origin of the flood.*—The genesis of this flood is, therefore, as follows: The Lower Mississippi was at a moderately high stage at the opening of the year, the gauge reading being 9.2 feet above the normal at St. Louis, 21.2 feet at Cairo, 16.7 at Memphis, 18.4 at Vicksburg, and 4.8 at Carrollton. For the first ten days of January the river at St. Louis, Cairo, and Memphis was falling slowly, but, from the effect of rains in the basins of the St. Francis, White, and Yazoo, it was rising steadily at Vicksburg and points below. Upon the river, already well filled, was precipitated the first Ohio flood in January. The Tennessee was already rising at the beginning of the month, and the upper Ohio began to rise on the 6th. The flood reached Cairo on the 10th, and the river rose during the remainder of the month. The Ohio fell from the first of February, and the river at Cairo followed more slowly, but was still 3 feet above the danger line when a second flood came out of the Ohio. This rise came from the upper Ohio, as the Tennessee continued to fall throughout the month. The Ohio rose rapidly at Cincinnati from February 7 to 21. At the same time there was a sharp, but short, rise in the Mississippi at St. Louis. During the first swell of this flood the Mississippi, above the mouth of the Ohio, was slowly falling, and during the second swell was low, except for the slight rise at the end of February. The only effect of this was to make the rise at Cairo a little more sharp and high. It is clear that the flood of 1882 arose from heavy precipitation in the Ohio basin and the districts adjacent to the Mississippi below Cairo.

FLOOD OF 1883.

68. *Its single great rise.*—The hydrographs of this flood, Plate XXX, show the Lower Mississippi at its normal level at the beginning of January. The rise, which should have been in progress, under normal conditions, did not set in until the latter part of the month. From the 17th the river at Cairo rose in a great swell, attaining on February 27 the highest stage ever recorded. The decline during March was rapid to a stage 10 feet below the normal on the 26th. A second but much smaller swell immediately set in, reaching its maximum the middle of April. Both these rises came from Ohio floods; the first was aided by a rise in the Mississippi above Cairo, but the St. Louis hydrograph shows a stationary river during the second. At Memphis the river stages followed closely those at Cairo, but the maximum height attained during the first swell was only 1.8 foot above danger line, and the river remained in flood but twenty-three days; the danger line was not reached during the second swell. A small swell occurred in the Arkansas at the same time as the first at Cairo, and its decline coincided with that at Cairo. At Vicksburg the river rose in a single swell from

January 20, reaching danger line on February 24, and remaining in flood to May 17; at its maximum the stage was 2.8 feet above danger line. At New Orleans, also, there was a single swell, reaching its crest on April 7.

69. *The accompanying precipitation.*—The downfall of water during January, as shown in Tables XIX and XX, was deficient in all the basins except those of the Missouri and the Central Valley. In February there was a large excess in the Ohio basin, and smaller excesses in the other basins. In March the downfall was somewhat deficient except in the Missouri basin. These facts are further illustrated by the precipitation and departure charts, Plates XXIV to XXIX.

This is a type of a purely Ohio flood. A great flood out of the Ohio descended, in this case, upon a low river. The resultant flood is short in duration at Memphis. A second and much smaller flood, following from the Ohio, produced a second rise at Memphis, but at Vicksburg formed a continuation of the earlier swell. The prolongation of the latter at this point would seem to have been due to slow drainage through the St. Francis and Yazoo bottoms.

FLOOD OF 1884.

70. *Its main features.*—In this year occurred the memorable flood of the upper Ohio, in which the river at Cincinnati rose 69.2 feet above lowest water. At St. Louis the Mississippi remained at a nearly uniform low level from the beginning of the year to the middle of March, when a moderate swell began. The great flood wave in the Ohio, as shown by the Cincinnati hydrograph, Plate XXXVII, began on January 29, reaching its crest on February 14, and declining rapidly to March 6. This flood was immediately followed by a second of much less magnitude. The Mississippi, at Cairo, rose in two swells, the first beginning on February 1, reaching its crest at 11.8 feet above the danger line on the 22d. There was then a fall of about 16 feet to March 11, followed by a second and smaller swell, which reached its height on April 7 at 8.8 feet above danger line. Neglecting the few days between the two swells, when the river fell a little below the danger line, the river was in flood sixty-five days. At Memphis the two swells were evident, but much less marked than at Cairo; the flood reached a height of 1.2 foot above danger line, and its duration was fifty-three days. At Vicksburg the flood rose in one swell, somewhat accentuated at the time of its crest by the second rise. The river reached a height of 8.0 feet above danger line, and remained in flood one hundred and seven days. The single, long swell at New Orleans rose 2.7 feet above danger line, and the river was in flood one hundred and seven days.

71. *Distribution of rainfall.*—The precipitation of this flood is shown on Plates XXXI to XXXIII, and its departure from the normal on Plates XXXIV to XXXVI; its amount in the various river basins is given in Table XIX, and the resultant downfall in Table XX. In January the precipitation is seen to be above normal in the upper Ohio and Tennessee basins and the lower portion of the Central Valley. During February the downfall is very heavy in the Ohio basin, and exceeds the normal in all basins. In March the downfall is again largely in excess of the normal in the Ohio basin, and there is an increased downfall in the lower Missouri basin.

This flood was closely analogous to that of 1882. Each was caused by two flood waves from the Ohio, but in the former one the second wave was the greater, while in this the first was the more important. The duration of the flood of 1882 was much

longer. The first flood out of the Ohio descended, in the flood of 1882, upon a much higher river than in 1884. The latter flood, like the two previous ones, came essentially out of the Ohio, the second swell being somewhat increased by a rise in the Mississippi above Cairo. Short floods also came out of the Arkansas and Red rivers.

FLOOD OF 1890.

72. *The rise in three swells.*—The hydrographs of Plate XLIV show the Mississippi above Cairo to have remained at a low stage throughout the period covered. At Cairo the river rose in a short swell in January, reaching a height of 3.7 feet above danger line on the 21st; by February 8 it had fallen to a stage of 7 feet below danger line. A second small swell occurred in February. Toward the end of February the river again began to rise, and remained above the danger line from February 13 to April 14. The same three flood waves are seen at Memphis, where the river was in flood fifty-five days, and the water reached a height of 2.6 feet above danger line. At Vicksburg and New Orleans there is a single, grand swell, the rise at Vicksburg beginning on January 7, and culminating on April 26 at a stage 8.0 feet above danger line; at New Orleans the river also rose from January 9 and reached a stage 3.7 feet above danger line. In the Ohio there were three distinct rises, the first occurring in January and culminating in a stage 1.0 foot below danger line at Cincinnati; the second rise, in February, reached a height of 12.0 feet above danger line on March 1; the third rise began on March 11 and reached a stage 14.4 feet above danger line on March 26. No flood occurred in the Arkansas this year.

73. *Origin of the flood.*—The precipitation and departure charts, Plates XXXVIII to XLIII, show the heaviest downpour to have occurred over the Ohio basin. There was also heavy rainfall in the Central Valley and the basin of the White river. These facts appear in detail in Table XIX. The excess of downfall is shown, in Table XX, to have been wholly supplied from these sources, and here we again find a flood occasioned by water from the Ohio and the alluvial basins along the Mississippi below Cairo. The Missouri, Arkansas, and Red rivers play no part in the development of the flood.

FLOOD OF 1893.

74. *A summer flood.*—The hydrographs of Plate LI show a flood of somewhat different character and origin. The river at Vicksburg, after a slight spring flood of little moment, had fallen on April 17 to a stage 10 feet below its normal level for that date. It then began to rise rapidly, reaching the danger line on May 1, attaining a height of 7.3 feet above danger line on May 22, and remaining above danger line to July 1. At Cairo the rise began on April 11, reaching the danger line on the 17th, and its maximum height of 9.3 feet above danger line on May 8. This rise was succeeded by a rapid fall to the 26th, when a second small rise set in. From June 12 the river fell rapidly. The two swells are apparent at Memphis, where the flood rose to a stage 2.2 feet above danger line. A rise began in the Ohio, at Cincinnati, on April 6, and in the Mississippi, at St. Louis, on the 10th. At the former point the river rose to a stage of 5.9 feet above danger line by May 7, and at St. Louis the Mississippi reached a stage 1.6 foot above danger line on May 3.

75. *The cause of it.*—From the precipitation and departure charts, Plates XLV to

L, as also from the data of Table XIX, we see that the rainfall to which this flood is due fell, in April, over the Ohio and Upper Mississippi basins, the lowest section of the Missouri basin, and the upper districts of the Central Valley; in May the rainfall was above the normal over most of the Ohio basin, the southernmost part of the Upper Mississippi basin, and southward over the districts adjacent to the Mississippi. In June the downfall was rather below the normal over the entire Mississippi drainage basin. We find this flood to have arisen from the combined action of moderate floods out of both the Ohio and Upper Mississippi basins, aided by a heavy downpour over the Central Valley and White river basin.

FLOOD OF 1897.

76. *Its chief features.*—In the flood of last spring, as shown by the hydrographs of Plate LVIII, the river rose in one long swell at all stations from St. Louis to the gulf of Mexico. At St. Louis the rise began on February 2, and was slow, continuing, with minor oscillations, to May 2, when a stage 1.0 foot above danger line had been reached. At Cairo the rise commenced on February 4; it was checked by a slight fall from February 16 to 22; after which it continued to a maximum of 11.6 feet above danger line on March 25. The subsequent fall was slow to April 16, and afterward became rapid. The river was at flood height for a period of fifty-nine days. The course of the flood at Memphis was altogether similar to that at Cairo. The rise, commencing on February 7, was checked by a slight fall from the 19th to 24th, and then continued to a maximum stage of 4.1 feet above danger line on March 19. The fall from the latter date to the end of April was only 3 feet, then becoming more rapid. The rise at Vicksburg began on February 12, and the river came to a stand during the latter days of the month. From March 1 the rise was steady until the crest was reached at a stage of 11.3 feet above danger line on April 16. The rise at New Orleans was continuous from February 15 to May 13, when a stage of 6.1 feet above danger line was reached. A sharp rise occurred in the Ohio at Cincinnati from February 3 to 11, followed by a fall to the 20th. A still more rapid rise then set in, lasting to the 26th, when the river was 16.4 feet above danger line. This flood from the upper Ohio was followed by a great rise in the Tennessee and Cumberland rivers during March.

77. *The rainfall and probable drainage.*—From the precipitation and departure charts, Plates LII to LVII, it is seen that the downpour of this flood fell much short of that in the notable flood of 1882. In January there was abundant precipitation in the lower Missouri and Arkansas basins and the Central Valley, which filled the bottoms, and brought the Mississippi to its normal winter height. In February a rainfall, not of excessive amount, but falling within a short time, occurred in the Ohio basin, and inaugurated the flood. In March still heavier rainfall in the Ohio basin, and especially on the Cumberland and Tennessee watersheds, maintained the lower Ohio in flood. This was supplemented by a slow rise from the Mississippi above Cairo, caused by moderate rains in the lower sections of the Missouri and Upper Mississippi basins. At the same time heavy rainfall occurred in the Central Valley and the lower Arkansas basin. The departure of downfall in the Ohio basin, from its normal value, is seen trom Table XX to be much less than half its amount in 1882, and yet the Ohio flood is fully the equal to that of 1882. This must be explained by the rapidity of the fall of water, a short and rapid rain supplying an immediate flood drainage equal

to that of a much greater rain at a slow rate of fall. The downfall in the Missouri basin is very greatly in excess of that in 1882, but is chiefly due to a very moderate rainfall over the great, dry plains which form the major part of its area. A comparison of the St. Louis hydrographs for the two years does not indicate that the Missouri discharge was increased to a degree corresponding to the stated increase of downfall.

78. *Source of the flood.*—The genesis of this flood appears to be as follows: The Lower Mississippi in the early part of February was at a low stage. Upon it was poured, during February, a great flood from the Ohio. At the same time the alluvial bottoms were filled by heavy rainfall. The river was brought to full flood by the middle of March. It was then maintained in flood chiefly by heavy rainfall over the Central Valley and lower Arkansas basin, somewhat aided by higher water in the Mississippi itself above Cairo.

COMPARISON AND CAUSE OF FLOODS.

79. *Relative importance of these six floods.*—In the following small table are shown the heights above the local danger lines reached in these six floods at several typical points:

TABLE XXI.—*Heights of six floods, stages referred to local danger line.*

Station.	1882.	1883.	1884.	1890.	1893.	1897.
St. Louis, Mo.	+ 2.2	+ 4.8	− 1.9	− 9.4	+ 1.6	+ 1.0
Cairo, Ill.	+11.9	+12.2	+11.8	+ 8.8	+ 9.3	+11.6
Memphis, Tenn.	+ 2.2	+ 1.8	+ 1.2	+ 2.6	+ 2.2	+ 4.1
Vicksburg, Miss.	+ 7.8	+ 2.8	+ 8.0	+ 8.0	+ 7.3	+11.3
New Orleans, La.	+ 2.3	+ 2.8	+ 2.7	+ 3.2	+ 4.2	+ 6.0

It is difficult to decide the relative severity of these floods from the available records. This would be properly measured by the extent and depth of the overflow upon lands adjacent to the river, and these depend not only upon the stages reached on the river gauges, but also on the duration of high water. Below Cairo the highest river ever known occurred during the flood of 1897, but, in the duration of high water, the floods of 1882 and 1884 exceed that of 1897. The two great floods of 1882 and 1897 differ somewhat in character; the flood of 1882 was longest in total duration, but that of 1897 had greater duration of extremely high water. This is seen in the following comparative statement of the duration of various stages at the head of the alluvial plain at Cairo:

Stage of river.	1882.	1897.
	Days.	*Days.*
River above danger line	81	59
Two feet or more above danger line	68	56
Four feet or more above danger line	63	51
Six feet or more above danger line	47	47
Eight feet or more above danger line	15	42
Ten feet or more above danger line	9	19

It is seen that the earlier flood holds the lead until a stage of 6 feet above danger line is reached, but at higher stages, the later one has much the longer duration. A

more detailed account of the flood of 1897 will be given in Section IV, based upon the reports of Weather Bureau officials, who were present on the ground.

80. *Cause of Mississippi floods.*—It is, of course, conceivable that a flood should occur in the Lower Mississippi from heavy precipitation over any of the great contributary basins. In these floods of the past quarter-century, we do not, however, find the western tributaries playing an important part. The great source of floods is the Ohio basin, with its steep slopes from the crest of the Alleghanies, upon which fall the heaviest rains of spring, at a time when the normal rise of the Lower Mississippi brings the river almost to the danger line from Cairo to the Gulf. In the greatest floods, we also find that heavy rainfall over the great swamp region that extends along the Mississippi from the mouth of the Ohio to the gulf of Mexico, is an important factor. Third in importance, as a factor in producing floods, is the Upper Mississippi, which, while never discharging a volume sufficient to produce of itself a flood, yet, rising later than the Ohio, serves to prolong the high water, and thus to increase the overflow.

Crevasse at Stop Landing, Mississippi, after Subsidence of Flood.

SECTION IV.

SPRING FLOOD OF 1897.

Special reports on this year's flood.—Extent of the overflow.—Losses by the flood.—Work of the Weather Bureau.—Flood in the Ohio river: Sources to Wheeling, W. Va.—Wheeling to Point Pleasant, W. Va.—Point Pleasant to Lawrenceburg, Ind.—Lawrenceburg to Mount Vernon, Ind.—Mount Vernon to the mouth.—Tennessee river.—Flood in the Upper Mississippi river: Sources to Reeds Landing, Minn.—Reeds Landing to North McGregor, Iowa.—North McGregor to Clinton, Iowa.—Clinton to Burlington, Iowa.—Burlington to Quincy, Ill.—Quincy to Louisiana, Mo.—Louisiana to the mouth of the Missouri river.—Flood in the Missouri river: Sources to Fort Yates, N. Dak.—Fort Yates to Chamberlain, S. Dak.—Chamberlain to Vermilion, S. Dak.—Vermilion to the Little Sioux river.—Little Sioux river to Atchison, Kans.—Atchison to the mouth.—Flood in the Arkansas river: Sources to Dodge City, Kans.—Dodge City to the southern border of Kansas.—Southern border of Kansas to Dardanelle, Ark.—Dardanelle to the mouth.—Flood in the Red river.—Flood in the Lower Mississippi river: St. Louis, Mo., to Chester, Ill.—Chester to New Madrid, Mo.—New Madrid to Helena, Ark.—Effect of the St. Francis levee.—Helena to Vicksburg, Miss.—Vicksburg to the mouth.

DETAILED accounts of the spring flood of this year by officials of the Weather Bureau, who were on the ground, will be presented in the following pages. Early in April, when it became apparent that the flood would prove one of exceptional severity, those officials were directed to collect information in regard to it, and, at its conclusion, to render a report. To each of the various officials engaged in river work, was assigned a section of river upon which to report. This method was applied not only to the Mississippi itself, but also to the main tributaries, and in this section will be found the various reports—some perfunctory, and some carefully prepared and highly interesting.

It is doubtless impossible to obtain, from a written description, a full realization of the horrors of such a visitation as this great flood. The days of anxiety and nights of fear, before the dreaded waters begin to rise; the wearisome struggle to hold the protecting levee; the final hardship, when the flood has triumphed and only flight remains. These things are not to be measured by the money loss alone; besides this they mean, for many, sickness and death long after the flood has receded. As graphical illustration often helps to a clearer understanding than many pages of text, a few typical flood scenes have been reproduced from photographs taken during the progress of the flood, and will be found scattered through the book. The view, on the opposite page, of Stop Landing crevasse, which occurred on March 30, taken after the flood had subsided, shows the state in which flooded lands are left.

The reports from the flooded districts confirm fully the conclusions which we had already reached, from a study of the rainfall and hydrograph charts, as to the genesis of the flood. The general opinion of these officials is that the flood of this year was not equal to that of 1882, except at a few scattered points. The remarks in the report of Mr. S. C. Emery, Weather Bureau observer at Memphis, as to the effect of the St.

Francis levee, which has been constructed since the great flood of 1890, are specially interesting. The comparative table of gauge readings at Cairo, Memphis, and Helena, which he presents, seems to support his proposition that this levee, even in its incomplete state, has had the effect of raising the height of great floods three or four feet at the head of the Yazoo bottom.

81. *Extent of the overflow.*—The extent of the present flood has been carefully investigated. Charts were prepared by the Weather Bureau officials for the various reaches of the rivers, by the aid of reports obtained from the numerous correspondents of the Bureau in the flooded districts. Similar charts had also been prepared by the engineer officers in charge of the levee districts of the Lower Mississippi, and copies of these were kindly furnished to the Weather Bureau. From these sources the overflowed area has been charted, and is shown by the darker tint on the map of the alluvial regions, Plate II. This map, while, of course, not accurate in minute details, represents with substantial correctness the flooded area. From planimetric measurements the extent of the overflow in each section of the alluvial plain has been determined, and, together with the total areas of alluvial lowland in the respective sections, is given in the following table. The latter data are as given by the Mississippi River Commission in 1887, with the single exception of the section on the west bank, between Helena and Arkansas City, where the overflow of this year exceeded the stated area of alluvial land.

TABLE XXII.—*Extent of overflow areas.*

Reach of river.	In the past.	In 1897.
On the east bank.	*Sq. miles.*	*Sq. miles.*
Commerce, Mo., to Memphis, Tenn	616	583
Yazoo bottom	6,648	4,273
Vicksburg, Miss., to Baton Rouge, La	415	11
Baton Rouge, La., to the Gulf	2,901	12
On the west bank.		
St. Francis bottom	6,090	2,660
Helena, Ark., to Arkansas City, Ark	1,152	1,152
Tensas bottom	4,955	3,113
Basin of Atchafalaya Bayou	6,085	884
Basin of La Fourche Bayou	2,024	890
Total	29,986	13,578

82. *Losses by the flood.*—The precise extent of the loss resulting from a great flood is impossible of estimate. This loss results from many causes, among which we may enumerate the destruction of buildings, fences, levees, and similar constructions; the drowning of stock; the ruin of growing crops, and, if the flood is late in the season, the prevention of subsequent planting and hence the total loss of the year's crop; the injury to land by covering it with sand and débris, a loss that is probably in the total more than counterbalanced by the general enrichment of the soil by the deposit of rich alluvion; and the injury or carrying away of implements and movable property. The loss to wage earners by the cessation of work is also a large factor in the damage inflicted by flood.

By a consideration of the overflowed area, as shown on Plate II, the statistician of the Department of Agriculture has estimated the value of movable agricultural property in the flooded district at the beginning of the flood at about $15,000,000, as follows:

Horses, cattle, sheep, and other live stock	$10,037,540
Corn, oats, cotton, and other movable products, of last year's crop	4,664,900
Total	14,702,440

This, it will be noted, includes no real estate and no personal property, other than stock and crops, the greater part of which was moved to places of safety as a result of Weather Bureau warnings.

83. *Work of the Weather Bureau.*—The River and Flood Service of the Weather Bureau embraces at the present time one hundred and thirteen river stations at which the height of river, together with certain meteorological data, is observed. These are supplemented by seventy-five rainfall and special stations, from which reports are obtained in time of flood. These stations are grouped about certain centers, at which their reports are collected. The essential duty of the Weather Bureau in this work is the issuance of warnings of impending floods. For this purpose the official at each river center is assigned a certain territory, for the proper warning of which he is held responsible.

From the press reports and other sources of information, it appears that this duty was well performed in the late flood. The conditions having become critical, a special warning was issued from the Washington office on March 15, that "the impending flood will prove very destructive in Arkansas and northern Louisiana." Again, on March 19, a special warning was issued that "the floods in the Lower Mississippi during the next ten days or two weeks will, in many places, equal or exceed, in magnitude and destructiveness, those of any previous years, and additional warning is given to the residents of the threatened districts in Arkansas, Louisiana, and western Mississippi to remove from the region of danger." Indeed, so completely was the public warned that it caused criticism, in certain quarters, that the Bureau was needlessly alarming the people in the threatened districts. Subsequent events, however, fully justified the action of the Weather Bureau.

There follow, in the subsequent paragraphs, the detailed reports upon the river conditions of the past spring. These are grouped with respect to the five great tributaries, the Ohio, Upper Mississippi, Missouri, Arkansas, and Red, as well as the Lower Mississippi itself.

THE OHIO RIVER.

84. *Sources to Wheeling, W. Va., reported by Mr. Frank Ridgway, Local Forecast Official, Pittsburg, Pa., June 16, 1897.*—Both the Alleghany and Monongahela rivers originate in and flow through hilly and mountainous districts, and are subject to frequent floods, which are characterized by an overflow confined to narrow limits, and a very rapid subsidence. Agricultural interests suffer little, the damage being confined almost entirely to navigation, railroads, and manufacturing establishments.

During the spring of 1897 two floods occurred in western Pennsylvania—the first, in February, being confined to the Monongahela, and the other, in March, to the Alleghany watershed. On February 20 rain began to fall over the Monongahela valley, and continued until the early morning of the 23d. The rain was general in character and averaged over two inches on the 21st and 22d, causing the Monongahela river to rise from a moderately low stage on the 21st to a flood stage during the early morning

of the 23d. The river continued high all day and the following night; the fall was not rapid until the night of the 24th. The banks were overflowed at many points, but practically no damage resulted in the headwater districts. In the lower districts transportation, shipping, and manufacturing interests suffered greatly, the damage, at a conservative estimate, amounting to about half a million dollars. It is further estimated that the loss to wage-earners, by being thrown out of employment while the water flooded the mills, and while repairs were being made, amounted to at least $400,000, which brings up the figures representing the entire loss on account of the flood to nearly $1,000,000.

On March 1 from one to two inches of snow remained on the ground over the larger part of the watershed of the Alleghany river and its tributaries. The mild temperature during the first week of the month caused the snows to melt, and this, supplemented by the general rains which fell over western Pennsylvania during the same period, caused flood conditions in the Alleghany river on the 6th. The only damage caused by the high water, was in the delay of railroad traffic while tracks were submerged. During the floods of both February and March the upper Ohio overflowed its banks at several points, but no considerable damage is reported to have been done.

85. *Wheeling to Point Pleasant, W. Va., reported by Mr. H. L. Ball, Observer, Parkersburg, W. Va., June 18, 1897.*—On the eastern border of West Virginia the Alleghanies traverse the state its length, and form a watershed, eastward to the Atlantic, westward to the Ohio, four-fifths of the state draining westward. The surface of the state, scarified and torn by a multitude of mountains, threaded by numberless valleys, and bounded on the west by the undulating basin of the Ohio, represents every sort of topography. The serrated hills and tortuous ravines are waterways down which often sweep mighty torrents. So rapid is the fall of the streams that a downpour of rain in the hills is followed in the narrow valleys by a rush of water as of a tidal wave, and which as quickly recedes; and it is only when the more sluggish Ohio is reached that the march of the flood becomes less riotous. In the interior, floods may and often do occur which have no great effect upon the Ohio, but do great damage to crops and property along the smaller streams.

At the outset it may be stated that, in West Virginia, the floods of February and March, though great, were not unprecedented or disastrous. At the opening of February from 6 to 10 inches of snow lay upon the mountains in the northern part of the state. Cold weather had prevailed and the rivers were frozen. Increasing warmth and general rains caused a break-up, and from February 7 to 10 the rivers were full and running freely. Such were the conditions preceding the general and heavy rains which fell from the 20th to the 24th of the month. The average rainfall during these four days, over that part of the state draining into the Ohio, was 3.3 inches, and over that draining into the Potomac, 2.7 inches. The rivers, already full, were made raging torrents, especially those emptying into the Great Kanawha. Sudden and heavy rises occurred in all the mountain streams, and the danger line was reached at many points. In the Monongahela, the Cheat, the Potomac, and the Great and Little Kanawhas, the rise began on the 22d, and reached its highest on the 23d and 24th. The Ohio felt the heavy rains almost as quickly as the smaller streams, and the latter were choked by backwater, and overflowed their valleys. The most sudden and serious rises occurred in the Monongahela and the Great and Little Kanawhas.

The river stages at Parkersburg and Marietta are practically the same, except when a rise occurs in the Little Kanawha. During the period under consideration, very heavy rains fell along the Muskingum and Little Kanawha rivers, and these were immediateiy felt in the Ohio at Parkersburg. The river began rising on the 22d, and rose rapidly until the 25th, when it reached a maximum stage of 37.9 feet, the crest of the wave passing at 4:15 p. m. The Little Kanawha during this time was out of bank along all the lowlands, and immense quantities of timber and railroad ties were washed from the side streams into the Ohio. Freight traffic on the Ohio River Railroad was abandoned, and several hundred families living along the river front were compelled to move to high ground. No direct loss was occasioned by the high water, other than the washing away of lumber and ties, the Weather Bureau having issued flood warnings in ample time for the moving or securing of other property. The stage of water at Parkersburg was not unusual.

The Elk, Coal, Gauley, Guyandotte, and Big Sandy rivers were flooded, and immense quantities of lumber and ties were washed away, and many families on the lowlands were driven to high ground. No accurate statement can be given of the loss, but $250,000 appears to be a conservative estimate, founded upon the general reports through newspapers and otherwise. While the floods were undoubtedly great and widespread, they were by no means unprecedented or unusually disastrous. There is not found recorded the loss of a single human life, and the suffering caused by the necessity of moving from habitations was no more than could be expected by people who will live along the river fronts.

86. *Point Pleasant to Lawrenceburg, Ind., reported by Mr. S. S. Bassler, Local Forecast Official, Cincinnati, Ohio, June 5, 1897.*—Except at the cross valleys, through which the large tributaries—the Great Kanawha, Guyandotte, Big Sandy, Scioto, and the two Miamis—flow, the country along the Ohio river, between Point Pleasant and Lawrenceburg, is fairly well protected from serious overflows by the series of hills and highlands through which the mighty volume of water, gathered mainly from the mountainous territory of West Virginia and western Pennsylvania, is swiftly carried to the Lower Mississippi.

A remarkably good stage of water and great activity in river traffic, for the season of the year, prevailed during January up to the 27th, when navigation was suspended on account of increasingly heavy floating ice. Ice gorges formed, which, under the influence of milder weather and rain during the first part of February, were broken up and carried away without damage of any consequence. Navigation on the Ohio river was twice suspended during the month of February, which was characterized by a continuation of the January ice-run and by high water. Since 1860 only two higher stages than that of last February have occurred—one in February, 1883, and the other, and greatest in the history of the river, in February, 1884. Sudden and almost simultaneous rises at all points in the Ohio valley, due to general and extraordinary rainfall, were the remarkable features of the 1897 flood.

At Point Pleasant the Great Kanawha, one of the most important tributaries of the Ohio, pours the water collected in southern West Virginia, western Virginia, and the northwestern corner of North Carolina into the main stream. The land at Point Pleasant is hilly, and comprises two terraces, the first extending to Seventh street, and the second to Thirteenth street. At a stage of 52 feet the water entirely covers the

first terrace. During the high water of February about one-half of the town was flooded from 1 to 7 feet in depth. The damage was small and has not been estimated. The river observer reports that advantage was taken of timely flood warnings issued, and only the few who ignored the warnings suffered.

The following table shows the danger line and river stages at points named, during the time of highest water, between Point Pleasant and Cincinnati:

Date.	Point Pleasant, W. Va. Danger line, 36 ft.		Cattlettsburg, Ky. Danger line, 50 ft.		Portsmouth, Ohio. Danger line, 50 ft.		Cincinnati, Ohio. Danger line, 45 ft.	
	Stage.	Rise in 24 hours.	Stage.	Rise in 24 hours.	Stage.	Rise in 24 hours.	Stage.	Rise in 24 hours.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
February 21	19.5	1.5	24.1	1.2	25.5	1.0	29.5	0.4
February 22	30.2	10.7	37.5	13.4	37.0	11.5	41.0	11.5
February 23	45.0	14.8	52.4	14.9	51.8	14.8	50.4	9.4
February 24	50.9	5.9	56.0	3.6	57.4	5.6	56.0	5.6
February 25	52.3	1.4	58.5	2.5	59.0	1.6	59.4	3.4
February 26	50.5	....	56.5	....	58.1	....	61.1	1.7

For 15 miles from its junction with the Ohio the Guyandotte river was overflowed. Guyandotte, W. Va., was nearly all under water. Proctorville, Ohio, on the opposite side of the river, is situated on a long stretch of bottom land, and was about two-thirds overflowed. The highest stage over this area of bottom land occurred on February 24, and the overflow on both sides of the river was 3 miles wide, water remaining in the bottom for ten days. Much distress and many losses were sustained along this part of the river. It is estimated that the damage to the town and farms in the vicinity would reach not less than $10,000. Nearly the entire city of Catlettsburg, Ky., was covered with from 1 to 7 feet of water. The lowlands along the Big Sandy were overflowed, as is generally the case when that tributary gets out of its banks. It is estimated that $5,000 will cover the damage done at Catlettsburg. The water was above the danger line for six days.

At Portsmouth, Ohio, the Scioto joined with the Ohio in making the rise both rapid and strong, and in less than four days covered 33.5 feet on the gauge. The water overflowed the lowlands from 1 to 6 feet, and a little over one-third of the city was flooded, including Mill and Front streets, the greater part of Third street, and the low portions of a great many other streets in both the dwelling and business districts, compelling occupants of dwellings and business houses to vacate first floors. A warning that the river would pass the danger line (50 feet) had been sent out by the Weather Bureau. This enabled those whose property was in jeopardy to move their goods to places of safety. For a distance of about 5 miles above its mouth the bottom lands of the Scioto river average about 2 miles in width. Over these bottoms the water was 20 feet deep. In Kentucky, opposite Portsmouth, high hills closely border the river. The total land submerged in and near Portsmouth was about 9,900 acres, and the estimated damage was $10,000.

The Little Miami river flows into the Ohio just east of Cincinnati, through a stretch of fertile bottom land. This serves as a storage reservoir for an immense amount of backwater. The overflow into the Little Miami valley extended about 4 miles up the stream, and was, on an average, 1 mile wide. Cincinnati had ample warn-

ing of the impending flood. On the morning of February 23 the rapidly rising river had exceeded the stage forecasted by 0.4 foot. Careful calculation and the use of the telegraph confirmed the opinion that 60 feet, if not more, would be reached at Cincinnati. The warning was therefore renewed, and, at 9 a. m. of the 26th, the river came to a stand at 61.2 feet. Great damage by water to goods and merchandise in cellars throughout the wholesale districts, usually covered by floods, was averted by prompt removal. The total loss from all causes, resulting from the flood, is estimated at $150,000 at Cincinnati, $30,000 in the Mill Creek bottom, and about $25,000 along the mouth of the Licking river.

Below Cincinnati there was comparatively little loss until the bottom lands of the Big Miami river were reached, where there was an overflow. Lawrenceburg, Ind., suffered no loss this year, thanks to the new Government levee, which withstood the pressure of the water.

87. *Lawrenceburg to Mt. Vernon, Ind., reported by Mr. Frank Burke, Local Forecast Official, Louisville, Ky., June 20, 1897.*—The conditions prior to the spring flood of 1897 did not, in any manner, give reason to apprehend a serious rise. There was an almost total absence of snowfall; the early spring rains were generally moderate, and only sufficient to maintain a fair stage of water until February 22. Upon this date excessive downpours caused the stream to swell rapidly, and brought it above the danger line at Louisville on the 24th, and at Mt. Vernon on the following day. It attained its maximum height, 35.4 feet, at the former place on the 28th, and, except for the interval from March 5 to 10, was above the danger line until March 16, after which the water subsided rapidly, and at the close of the month had resumed its normal stage. At Mt. Vernon the rise began on February 8, and on the 12th the water was close to the danger line, near which it hovered until the 25th, passing it upon that day, remaining from 5 to 10 feet above it until March 26, and attaining its maximum height of 44.9 feet on March 17. During the latter days of the month the water was receding very rapidly.

To the succession of heavy rains, occurring between February 22 and March 10, the main rise can be attributed. All the smaller tributaries of the Ohio, especially those entering the river from the northern side, were bank-full during this period, and the outflowing waters maintained the stream at a flood stage for a month or more. The topography of the country along the river banks from Lawrenceburg to Lewisport, Ky., precludes any very great damage, even from an exceptionally high stage of water. The hills rise abruptly from the water, or are separated from it by lowlands, ranging from a few hundred yards to half a mile in width. From Lewisport to Mt. Vernon the distance between the hills on either side of the river gradually increases, the lowlands being rarely less than a mile, and in many places 5 miles wide. During the climax of the flood these lowlands were under water, but only for a short time, and practically no damage resulted in this section. The greatest loss was occasioned by the smaller streams in Indiana washing out tracks, bridges, and culverts, and causing an almost total suspension of traffic on the railroads entering Louisville from the north, for the week subsequent to March 6.

At Evansville, Ind., the greatest apprehension was felt in regard to the threatened cut-off above the city. Evansville is located on what is known as the "Horse Shoe Bend," opposite a projection of the Kentucky shore in the shape of a peninsula. During

every high water a current is formed across this peninsula, about 8 miles above Evansville, and empties just above Henderson, Ky. It was supposed that this current was more dangerous than usual, owing to the fact that an ice gorge, which had formed just before the rise of the river, had worn away the channel, and that a strong current would flow through and possibly divert the river itself. Though the action of the water was not continued long enough for this to happen, it was considered necessary by the United States engineers to take steps to prevent a recurrence of the trouble.

88. *Mt. Vernon to the mouth, reported by Mr. P. H. Smyth, Observer, Cairo, Ill., May 29, 1897.*—During this spring, for the fourth time in thirty years, the river at Cairo reached a stage exceeding 51 feet. The flood in the lower Ohio valley did not, however, equal in magnitude nor destructiveness the floods of 1882 and 1884. At most points the water lacked 3 to 7 feet of being as high as in 1884, but at Mound City, Ill., the river reached a stage 3 inches higher than the previous high-water mark. This unusual stage is believed to have been due to the Government gravel road, which runs from Mound City to Mound City Junction, a distance of about 3 miles, and has been constructed within the past four years.

At Cairo a great volume of water, instead of taking its natural channel, passed over the embankment at Birds Point, Mo., nearly opposite the mouth of the Ohio. This water reentered the Mississippi at Lucas' Bend, a point about 14 miles below. On the Kentucky side the water was over the lowlands and bottoms for from four to six weeks. All lowlands in the vicinity of Paducah, Ky., and the lower portions of Paducah itself were flooded from March 3 to April 18, forty-seven days. A conservative estimate of the money value of property destroyed or damaged by this spring's flood, in the lower Ohio valley, is $175,000. Many thousands of acres of wheat were drowned out and ruined, and thousands of bushels of corn in cribs were destroyed. The loss of stock was very small, it having been removed to places of safety. For nearly one month navigation was considerably interfered with, and river business was practically at a standstill during the period of high water.

89. *Tennessee river, reported by Mr. L. M. Pindell, Observer, Chattanooga, Tenn., June 17, 1897.*—In July, 1896, a protracted spell of dry weather set in, which continued during the rest of the year, except for a few heavy showers in December. With a dry spell, extending over a period of six months, it was to be expected that the early spring would be accompanied by heavy precipitation. In February, 1897, the rainfall saturated the earth, and, when March opened with heavy precipitation, the water drained quickly into the streams. The precipitation was heavy during the whole of March, thus keeping the streams well filled; the total rainfall ranged from 7 to 13 inches over the watershed. General and heavy rain fell over the entire river on the 6th, 12th, 14th, and 19th, and heavy rain at a few stations on the 9th, 10th, 16th, and 18th; from the 3d to the 23d the rain was almost continuous. The river rose from the 4th to the 14th at Chattanooga. The Clinch river, at Clinton, had three distinct rises, and the Tennessee, at Rockwood, had two, and at Chattanooga three rises during the month; at Chattanooga the crests of these rises occurred on the 8th, 14th, and 22d, respectively. At Lower Muscle Shoals the river observations were discontinued on the 19th (the gauge reading at that time being 17.7 feet) on account of the water being over the gauge; the observations were resumed on the 24th. Another rise followed

the heavy rainfall which occurred during the first five days of April, but the river did not reach the danger line at any point above Florence.

At Chattanooga the river covered the lowlands and bottoms from February 25 to 27, March 13 to 18, and on the 21st and 22d, in all ten days. It is estimated that 5 square miles were covered by water; the flood of 1867 covered about 30 square miles. The river reached the highest point, 38.2 feet, at 3:30 p. m. on March 14, and remained stationary up to 9:30 p. m., when it began to fall. After April 6 the river declined gradually until May 11, when another rainy spell set in, causing the river to rise until the 22.4-foot mark was reached on May 15. Since that date dry weather has prevailed, and the river has fallen to low water. At Florence, Ala., the river began to rise on March 6 and to fall on the 20th, reaching a stage 1.4 foot higher than any previous flood.

At Riverton, Ala., the rise commenced during the day on February 23, the gauge reading at 6 a. m. on that day having been 7.5 feet. The water rose rapidly until the evening of March 2, when the gauge read 26.6. This water all came from the upper river and the reports from above Chattanooga were so alarming that extensive preparations were made at the Government works here to protect perishable and floating property. Notwithstanding these reports and indications, a rapid fall occurred between the 2d and 6th of March, the gauge reading 14.3 feet at 6 a. m. on the 6th, a fall of 12 feet in four days. On the 6th the water commenced to rise rapidly. Until the 11th the rise was due entirely to water from above this point. On the night of the 11th there was an unusually heavy rain, inaugurating a series of frequent and heavy showers, which culminated on the night of the 17th in a storm of unusual severity. The rain fell in torrents almost continuously for forty hours, beginning about 9 p. m. on the 17th, and stopping about 1 p. m. on the 19th. The quantity of rain which fell during this period is estimated at 8 inches. The effect of this rain, falling as it did on ground already saturated with water, was marked, as is best shown by the record of the river gauge, which was as follows:

March 18, 6 a. m., 41.1; 6 p. m., 43.0.
March 19, 6 a. m., 47.3; 6 p. m., 49.6.
March 20, 6 a. m., 50.3; 6 p. m., 49.7.

Between 6 p. m. on the 18th and 6 a. m. on the 19th the rise was most rapid, amounting to 4.3 feet, and attaining a rate of 6 inches per hour during part of the time. The crest of the rise reached Riverton during the early morning of the 20th, at which time the gauge read 50.3 feet. The records of 1867 and 1875, which are said to be identical in this neighborhood, were exceeded by about 2.5 feet. Between March 6, when the second rise began, and March 20, when it culminated, the river rose a total of 36 feet, making an average rate of over 2.5 feet per day, and a maximum of 6.2 feet from the 18th to 19th. The overflowed district includes practically all of the land between the bluffs from Florence to Pittsburg Landing, a distance of over 60 miles. The average distance between the bluffs is estimated at 2 miles.

At Johnsonville, Tenn., the river reached 48 feet on March 24, being 27 feet above danger line. It had passed the danger line on February 28, and did not fall below it until April 18. The river reached the same stage as it did in the high water of 1882. The lowlands above and below the city were submerged. The river was out of its banks nearly four weeks. The highest point was reached at the mouth on March 24,

at a stage of 50.9 feet; the highest stage ever reached was on February 22, 1884, when the river reached 54.5 feet. The overflow along the lower Tennessee was from 1 to 4 miles wide.

THE UPPER MISSISSIPPI RIVER.

90. *Sources to Reeds Landing, Minn., reported by Mr. P. F. Lyons, Observer, St. Paul, Minn., May* 12, 1897.—The recent high water in the rivers of Minnesota may be traced back to the abnormally heavy precipitation of October and November, 1896, supplemented by the rather early setting in of freezing weather, and, while not a severe, still a rather long winter, with a much more than average snowfall. The accumulation of snow on the ground during January, February, and most of March, was far in excess of anything seen since the winter of 1880–81. In the spring following that winter the rivers attained the highest stages of which there is a reliable record, during April and May, 1881. The rainy season, which had its beginning in Minnesota about the middle of March, was by no means marked; in fact, the rainfall from that date to April 30 was rather light, and considerably below normal. No damage of consequence resulted from high water along the St. Croix; on the Mississippi the boom companies sustained the major portion of damage, which is estimated at $60,000, from the breaking of booms and the escape of millions of feet of logs, that floated down the river and were finally gathered up about lake Pepin.

The high water attained the maximum stage at St. Paul on April 6, at 18 feet; this stage was equaled April 16, 1875, and was surpassed April 29, 1881, when the extreme record of 19.7 feet was made. The river remained above danger line (14 feet) from April 1 to 18; after that there was a gradual and steady fall.

91. *Reeds Landing to North McGregor, Iowa, reported by Mr. M. J. Wright, Jr., La Crosse, Wis., June* 4, 1897.—With the exception of the highest lands, the entire Mississippi bottom, from Reeds Landing to North McGregor, a distance of 147 miles, was overflowed. The width of the bottom, from bluff to bluff, in this section averages 3 miles. At Winona, Minn., the highest stage of water, according to the records kept by the Chicago and Northwestern Railway Company, at the bridge, was 6 inches lower than in 1880. One death by drowning was due directly to the flood, that of a child of two and a half years. The flood in the vicinity of Winona was nearly if not quite as severe as in 1880, although the damage was small. Some of the residents on the shores of lake Winona had to move out of their houses on account of high water.

Along the shores of lake Pepin there is very little land subject to overflow, but on April 18 a very high south wind, veering to the west, washed the water over the banks and undermined the roadbeds of the Chicago, Milwaukee, and St. Paul, and the Chicago, Burlington, and Northern railroads, but traffic was interrupted for only a couple of days. The ice moved out of lake Pepin on April 5, thawing before it reached beyond Winona. It is a very unusual occurrence for ice to move out of lake Pepin, as it usually melts in the lake. It is presumed that a high northerly wind, which prevailed shortly before the ice in the lake broke up, was the cause of its moving out this year.

Ice moved out of the Chippewa river into the Mississippi the latter part of March, and the log jam moved out on April 3, at 11 a. m. Many square miles of land were overflowed in Buffalo and Pepin counties, Wis., and Wabasha county, Minn., during April. The area of country known as the Chippewa bottoms is rather thickly settled,

stock and hay being raised exclusively. Previous to the rise these settlers moved their families and stock to adjacent high land, and did not return to their homes until the water subsided, which was about the end of April. This section was overflowed from three to four weeks. The Chippewa gorge moved out and thawed so gradually that the only damage resulted to overflowed lands and delayed trains. A large amount of lumber and logs were scattered over the Chippewa bottoms.

In the vicinity of La Crosse the Mississippi, La Crosse, and Black rivers overflowed their banks, the water covering some farming lands and bottoms. At La Crosse the highest stage of water reached was 13.7 feet, and the flood lasted about ten days. From April 5 to 19 the levee, from State street to the wagon bridge, was covered with several inches of water, and the tracks of the Chicago, Milwaukee, and St. Paul railroad, on Front street, were submerged. The damage was small, as the Weather Bureau had given warnings of the approaching flood, and the occupants of buildings on the levee had removed from their basements all goods that were liable to be damaged by water. The large area of the city, known as the North Side, was overflowed, and several families had to vacate their houses. The Onalaska electric car line was submerged for about ten days, during which time no cars could be run. The damage to the Mississippi bridges at this point, from high water and floating ice, was $2,500, and the damage to railroad property is estimated at an equal amount. The cost of picking up the drifting logs this spring was estimated at $10,000, and a large number of logs were never recovered. The flood of 1880 was more severe in many respects.

92. *North McGregor to Clinton, Iowa, reported by Mr. L. M. Tarr, Observer, Dubuque, Iowa, June 18, 1897.*—The tributaries of the Mississippi in this section are numerous, but are all very small streams, except the Wisconsin, Galena, and Maquoketa rivers. The water was high in these and the smaller streams, but no serious damage was done, with the exception of the washing away of two or three small county bridges. The Mississippi between North McGregor and Clinton runs for the entire distance between high bluffs, which prevent it overflowing much arable land. The water began rising before the ice went out, which was on March 19 at Dubuque, and it continued to rise slowly but steadily until April 15, when the highest point, 17.9 feet, was reached at this place. This was 2.9 feet above the danger line, and 3.9 feet below the high water of June, 1880. At North McGregor the river reached its highest point, 17.6 feet, on April 13, and was then 0.4 foot below the danger line. The river rose slowly, and the daily river bulletins from this office kept the people informed of river conditions, and there was ample time to prepare for the rise. There were no lives lost and no serious damage was done in this section.

In the cities and villages along the river a few families occupying houses in low places had to move out for a few days, and basements and cellars were flooded. The lumber yards in Dubuque were at considerable expense in moving lumber on low ground, but none of it was washed away. The damage by the high water between North McGregor and Clinton was very slight. The Chicago, Milwaukee, and St. Paul railroad runs the entire distance along the west bank of the river, and the Chicago, Burlington, and Northern runs on the east bank. These roads are very close to the river for the entire distance, and yet they suffered no inconvenience from the high water. There were no washouts on either road, and no trains delayed.

93. *Clinton to Burlington, Iowa, reported by Mr. F. J. Walz, Local Forecast Official, Davenport, Iowa, May 15, 1897.*—The water did not begin rising with much rapidity at Clinton until April 5, and the flood crest of 16.8, or 2.8 feet above the danger line, was reached on April 17. The highest stage at Burlington was 13.3, or 3.3 feet above the danger line, on the 19th. The water registered 13 feet at Burlington on the 20th, and remained nearly stationary until the 27th, after which a rapid fall began. The river received a considerable increment, which showed on the gauge at Burlington, from the Iowa river, and this was due to the heavy local rains over central and southeastern Iowa. The islands and lowlands in the vicinity of Clinton were generally inundated, but only slight damage resulted, as they are sparsely populated, and are cultivated to only a small extent. A few houses in Clinton, mostly very cheap ones, occupied by the poorer classes, were flooded so that the occupants had to abandon them.

From Clinton to the mouth of the Wapsipinicon river some 5,000 acres were overflowed on the Iowa side of the river, including the islands, and of this area not over one-third is cultivated land. On the Illinois side of the river the banks are high and the country well protected down as far as the mouth of Rock river, except in what is known as the Meredosia slough. The latter district was generally submerged, but as it is largely swampy, waste land, it could not be considered damaged by the flood. About the mouth and extending up the broad valley of the Wapsipinicon river are rich, fertile bottom lands under high cultivation. About 6,000 acres of land in this district, which include many fine farms, were inundated; but the damage even here will not be great, as farming operations had not yet begun, and the water receded and the land dried off in time to allow a late planting to be made. The hay crop, which is large in this section, is unhurt. Below the mouth of the Wapsipinicon, and on to Davenport, little or no damage was done. The river did not get out of its banks in this reach, and only a few islands, mostly uncultivated land, were overflowed.

In Davenport and Rock Island there was little or no damage other than the flooding, to a small extent, of cellars and basements in the business houses near the river. The Burlington, Cedar Rapids, and Northern line of railroad, running into Davenport, had to abandon, for a week or so, its tracks entering the city along the levee; but its trains were brought in and out over the tracks of another road, and no loss other than a little delay and inconvenience resulted. Below Davenport, Big Island, at the mouth of Rock river, was partly covered. From this point to Muscatine, Iowa, the river banks are high, and the country on both sides well protected from overflow at the highest stages of water. The islands in this reach were all pretty generally covered, but there is little or no cultivated land upon them, and what there is will be dried off in time to raise a crop. Muscatine island, extending from Muscatine nearly to the mouth of the Iowa river, and containing some 20,000 to 25,000 acres of the most valuable and highly cultivated land in Iowa, would have been entirely submerged had it not been so well protected by an excellent private levee, which extends along nearly the full length of it. This levee held intact, as it also did in the much higher flood of 1892. There was no break in it, except a slight one at the lower end of the island, which was of no consequence, and was soon repaired. The part of the island below Port Louisa, not protected by the levee, was entirely submerged, and considerable damage resulted. The area flooded, including the whole district on the Iowa side of the river, as far

south as the Iowa river, will amount to some 10,000 acres, and the damage done is about $70,000.

From Drury's Landing to New Boston, on the Illinois side of the river, the bottom lands, amounting to some 30,000 acres, of which about one-sixth is cultivated, were all overflowed. The damage in this district will aggregate $80,000. From the Iowa river, south to Burlington, there was a general overflow of the bottom lands and islands. In places the inundation stretched clear to the bluffs, some 6 or 7 miles distant from the natural shore line. On the Iowa side, in Louisa county, there were many excellent farms covered, and the damage here will amount to considerable. The land submerged is some 30,000 or 40,000 acres, the greater part of which is cultivated. The only cases of suffering and destitution on account of the flood, north of Burlington, occurred in this Louisa county district, and was principally among the tenant farmers in the Iowa and Mississippi river bottoms, and the subcontractors and laborers on the Government levee. Thieves (or Huron) Island, containing some 2,000 acres of farming land and having about 125 inhabitants, was entirely covered, and the occupants compelled to abandon it for a time. On the Illinois side of the river the land was overflowed from 2 miles below Oquawa to opposite Burlington (10 miles below) and 1 to 3 miles back. This land, however, is low and swampy, and very little of it available for cultivation.

94. *Burlington to Quincy, Ill., reported by Mr. F. Z. Gosewisch, Observer, Keokuk, Iowa, May 21, 1897.*—The usual rise, with the breaking up of the ice, began early in February, causing only a moderate stage, and by March 7, when the steady rise began, the river had fallen to the low stage of 2.4 feet at Keokuk. From this date the river rose, with some fluctuations, until the crest of the flood reached Keokuk on the morning of April 27, at a stage of 18.5 feet, then gradually falling to below danger line by the morning of May 5. From Burlington to Keokuk the river hills extend nearly to the banks, leaving but a narrow margin of land liable to overflow, except in Green Bay township of Lee County, Iowa, and on cultivated islands in the river in that vicinity. The losses at Green Bay are estimated at $7,000. In the city of Keokuk the losses were confined to the lumber district, which was covered with from 2 to 4 feet of water, and the damage will not exceed $1,000.

On the Illinois shore the river hills begin receding from the river at Warsaw, Ill. South of Warsaw the bottoms are protected by substantial levees, and comprise the Hunt, Lima lake, and Indian Grave drainage districts. The Hunt levee was broken between 6 and 7 miles south of Warsaw on the morning of April 27, at a place where repairs had been made after the flood of 1888, and where the new work joined the old. The break widened rapidly to 475 feet. The river at the time of breaking was 3 feet lower than the top of the levee. Within four days after the break 25,000 of the 30,000 acres in the district were flooded with from 2 to 6 feet of water. The water from the break in the Hunt levee spread over the Lima lake district, inundating the entire 14,000 acres embraced. The losses in these two districts are estimated at $64,000. The Indian Grave levee was not broken, but the district was overflowed early in January from the waters of Bear creek, and winter wheat was then destroyed, the later flood doing no damage.

On the Missouri shore the land is mostly unprotected bottoms. The Egyptian levee skirts the south bank of the Des Moines river, ending at Alexandria, Mo. The banks of Fox river are leveed to its mouth near Gregory, Mo., the levee then extend-

ing a short distance south, on the bank of the Mississippi. Owing to excessive rainfall during the month of March the levees were water-soaked, and much water soaked through the Egyptian levee at an early stage of the flood. On April 18 a considerable portion of the Missouri lands were overflowed, and the water began encroaching on the track of the St. Louis, Keokuk, and Northwestern railroad at a low point between Gregory and Canton, Mo. By April 24 southbound trains were abandoned, and on April 26 the Des Moines river poured over the top of the Egyptian levee, carrying out the railway track between the Des Moines river and Alexandria, Mo. The towns of Alexandria and Gregory were flooded. The Mississippi river, south of the Des Moines, was from 4 to 6 miles wide, extending inland to the foot of the hills.

95. *Quincy to Louisiana, Mo., reported by Mr. E. A. Nimmo, Observer, Hannibal, Mo., June 5, 1897.*—Copious rains, during the latter part of March and early in April, caused all creeks and sloughs along the river to be filled to overflowing. The river during this time continued to rise steadily, and on April 4 the gauges at Quincy, Hannibal, and Louisiana showed a rise of 7.5, 8.8, and 10.2 feet, respectively, since the 15th of the preceding month. On March 26 water began to invade all unprotected bottom lands between Quincy and Louisiana, and by April 3 the entire bottom, extending back to the bluffs, and aggregating about 31,200 acres on the Missouri side, and about 2,700 acres on the Illinois side, were submerged. During the period from April 5 to 14 the water receded somewhat, but by April 20 the bottom lands were again entirely covered and remained flooded until May 6. From this time onward the river fell rapidly, and on May 11 the water had entirely receded from the flooded district.

At Hannibal the high water caused much inconvenience to property owners and railway companies along the river front. The wharf and floor of the Diamond Jo packet house was flooded, and, at the highest stage, water covered the floor to a depth of 15 inches. The electric light plant, which is the property of the city of Hannibal, was entirely surrounded by water from April 26 to May 4, necessitating the use of boats to get to and from the building. During the time when the flood was at its height, considerable inconvenience was caused merchants on Main street by seepage, many cellars and basements having as much as 5 feet of water in them.

96. *Louisiana to the mouth of the Missouri river, reported by Mr. H. C. Frankenfield, Local Forecast Official, St. Louis, Mo., May 20, 1897.*—Heavy rains in Iowa and northern Missouri about March 19 caused a rapid rise in the Des Moines and Fox rivers, and the commencement of this rise was felt at Louisiana on the 22d. Before the crest of this rise had passed, the first waters of the flood wave from the north arrived, and thereafter there was a slow, steady rise for six weeks, with the exception of a slight intermission during the second week in April. From Louisiana to St. Louis the flood was less marked than that in the Illinois river. At the former place the river goes over the banks at a 12-foot stage, and this stage was reached on March 27. The crest occurred on April 30, the stage being 18.5 feet, or only 0.3 foot less than that of the great flood of 1892. The water did not again go below the danger line until May 10. About 20,000 acres of land were submerged on the Missouri side of the river, the Illinois side being protected by the Sny levee, which successfully withstood the flood. Twelve miles below Louisiana the private levees of H. L. Hart and J. W. Colwell were broken, and several thousand acres of fine farm lands overflowed. The loss in the vicinity of Louisiana was at least $75,000. In the vicinity of Clarksville, Mo., 10,000

acres were overflowed, and damage done to the amount of $40,000. The water covered all the lands, except those places where the bluffs extend to the river. From Alton to St. Louis all lowlands were flooded, but the damage was trifling. The crest of the flood wave reached St. Louis on May 2, when a stage of 31 feet was recorded, being one foot above the danger line. The water remained above the danger line until May 5, and has since been falling rapidly.

The heavy rains during the first week in January brought the Illinois river to a stage approaching the danger line throughout its upper portion. During the remaining portion of January, and during February, sufficient rain fell to prevent any decided recession of the water. Consequently, when the heavy rains of March commenced, the already overburdened river could carry no more water, and overflows took place along its entire course. The flood proper may be said to have commenced on March 1, reaching its crest at Hennepin on the 18th. Owing to the wide overflow and the very slight fall of the river bed, the crest traveled very slowly, reaching Peoria on the 23d, Havana on the 27th, Frederick on the 28th, Versailles on April 1, Naples on April 3, and Grafton on April 6. The decline was equally as slow, and the effects of the flood waters of the Illinois were felt at Grafton as late as May 5. The stages of the water during this flood were on an average about 6 feet lower than those of the great flood of 1844. On the upper river, above Hennepin, there was only a slight overflow, covering some bottom lands, with little or no resulting damage. A total area of 500 square miles was overflowed. The extent of territory covered was quite small, as compared with that covered by the great flood of 1844, when the river averaged from 10 to 15 miles in width from La Salle to Grafton, and from Hardin to Grafton united with the Mississippi to form one continuous river.

THE MISSOURI RIVER.

97. *Sources to Fort Yates, N. Dak., reported by Mr. B. H. Bronson, Observer, Bismarck, N. Dak., April 14, 1897.*—The past winter was an unusual one in North Dakota and Montana on account of the heavy snowfall, while the temperature was lower than usual, with the result that ice from 3 to 5 feet thick formed in all the streams, making an early break-up doubtful. The first part of March was unusually cold, and the lowest temperatures ever recorded in that month occurred in the second decade, but warmer weather soon followed, especially in Montana, which caused the snow to melt rapidly, and effected a breaking up of the ice in the Yellowstone river the latter part of March. It was expected that, when the water from the Yellowstone reached the Missouri, the latter would open, and that, on account of the thickness of the ice, much trouble would occur from gorges in the river. These expectations were only partly realized; the river broke at this point early on the morning of April 5, and after the ice had moved for a short time it gorged, overflowing the bottom lands and flooding the railroad tracks. These conditions prevailed in some parts of the river between the mouth of the Yellowstone and Fort Yates until the 11th, when the ice moved out and the river assumed its normal condition for this time of year. Aside from the delays to trains, no damage of any consequence was done, as there are very few people above this point along the river, and in most cases there was nothing to damage except some stock, which was removed early.

98. *Fort Yates to Chamberlain, S. Dak., reported by Mr. F. O. Stetson, Observer,*

Pierre, S. Dak., June 20, 1897.—Over nearly the whole drainage area above Chamberlain the snowfall, during the winter of 1896–97, was much heavier than usual, and in some sections was the heaviest on record. That the damage from high water on the portion of the Missouri under consideration, during the spring of 1897, was so small as to be inconsequential, is due to a fortunate combination of circumstances. The river opened gradually from below, the ice passing out from Chamberlain to Welland before it had started at points above; but few ice gorges were formed and these were not of sufficient size or strength to have any important effect; an alternation of warm and cool weather during the latter half of March allowed much of the snow-water to pass off gradually before the ice broke up, at the same time assisting in the melting and rotting of the ice, and thereby diminishing the danger of gorging. The formation of a gorge of considerable magnitude at Bismarck partially held back the water from above until the rise, due to the breaking up of the Missouri and its tributaries below that city, had begun to subside.

From Chamberlain northward to Welland the river opened on the 28th or 29th of March, the ice above remaining firm for several days longer. The first half of March was unusually cold, the average daily deficiency up to the 16th amounting to more than 16 degrees. The weather of the next five days was warmer than the average, and the temperature remained above the freezing point during not only the day, but also the greater part of the night. The snow melted rapidly, and on the 16th a thin layer of water was observed flowing over the ice in the river; by the following day this had increased to a depth of 6 inches; and on the 18th a volume of snow-water, two feet in depth, was passing down the river, continuing in somewhat smaller quantity on the 19th. Had the weather continued warm, the ice would probably have broken up at this time, but a succession of cold days kept the river closed until the water from melted snow had passed off.

Although the river from Chamberlain to Fort Yates was higher than for several years, it overflowed its banks at but one place, Rousseau, and here no damage whatever was done, unless the caving of the bank may be considered such. Considerable cutting of the bank also occurred at Fielder. High water at Chamberlain, although the river was not at that place out of its banks, caused some injury to the pier and dike of the Pontoon Bridge Company. This is the only damage to property reported from Chamberlain to Fort Yates. Near the mouth of the Little Cheyenne, at Forest City, the lowlands were overflowed on March 29, making it expedient for several families to remove for a short time to higher ground, but there was no loss to property. With these exceptions there were no floods, so far as learned, on this reach of the river.

99. *Chamberlain to Vermilion, S. Dak., reported by Mr. C. D. C. Thompson, Observer, Yankton, S. Dak., June 14, 1897.*—An unusually heavy fall of snow occurred throughout South Dakota during the past winter. The greatest amount, however, fell over that portion of the state lying east of the Missouri river. The ice in the river remained solid until about March 20, when it began breaking near Vermilion; it broke at Yankton on March 22, and at Chamberlain on March 26. As will be seen from the above dates the river began opening at the lower end of this reach, and gradually worked up stream. In this way there was little chance of ice gorges forming. Some few small gorges were formed below Chamberlain, causing the low and bottom lands along the river to be flooded, but not to any serious extent. The range in depth of water in the

Missouri river, from the time of the break-up to the time when the water subsided, was about 10 feet. I am unable to find a single case of loss of life caused by high water on the Missouri this spring, and, with the exception of the cutting out of some few acres of timber land, there was no loss of property.

The White river, draining a part of the Black Hills country and flowing into the Missouri just below Chamberlain, opened about March 15. The stream was unusually high, but the ice ran out quickly and did little damage. The Niobrara river drains a part of the Black Hills country and a portion of northwestern Nebraska. The exact time at which it opened could not be learned, but it was between March 15 and 18, and the river was not unusually high. The James river is about 700 miles long and a very sluggish stream. It drains a considerable portion of South Dakota east of the Missouri river, and several counties of North Dakota. Its course is through that portion of the Dakotas where the greatest amount of snow was reported last winter. The few warm days, from March 16 to 20, melted sufficient snow to cause the stream to flow bank-full for several days; then another warm spell, from March 25 to 31, raised the water out of the banks. The warm, heavy rains of the last day of March and the first four days of April broke the ice and started a marked rise, which carried almost everything on the bottom lands before it.

The warnings by telegraph from Huron and other points up the river gave all people living on the bottom lands ample time to remove stock and implements to high ground. Most people in this section (Yankton county) availed themselves of the warnings, thus saving many thousands of dollars worth of property. The rise, however, was so gradual after the first swell and before the ice moved out, that some farmers moved back too soon and were caught, though no report of loss of life is heard. The bottom lands along the James river are from 1 to 1½ mile wide, and in some few places nearly 2 miles. The depth of water on these bottoms is reported to have averaged about 16 feet, while, in some of the narrower places, a depth of 18 and 20 feet is reported. As late as May 12 a considerable portion of the bottom lands in the north part of Yankton county were still under water. The railroad companies were heavy losers by the floods on the James river. No eastern mail was received at Yankton from the evening of April 2 until noon of April 10, on which date some mail and express packages were transferred in boats. The loss to farmers on the bottom lands, which will be in the hundreds of thousands of dollars, comes from the fact that the water has subsided so slowly that they will lose the use of the ground for crops this year.

The standard by which floods are gauged in this section is the flood of 1881. In comparing the rise on the Missouri this year with that standard, it falls about 20 feet short, while the rise on the James river was about 8 feet higher this spring. The particular feature of the flood of 1881 was an immense ice gorge, while the flood this year is the direct result of the melting of the deep snow, and the heavy rains which occurred at the time the snow melted.

100. *Vermilion to the Little Sioux river, reported by Mr. U. G. Purssell, Observer, Sioux City, Iowa, June 19, 1897.*—No unusual stage of water has occurred at Sioux City, the highest point reached being 16.4 feet, which is 2.3 feet below the danger line. The breaking up of the ice in this section of the river occurred on March 19 and 20, and took place in a very orderly manner, without the formation of any gorges worthy of mention, and with a stage of water much lower than the average at breaking-up

time. The river rose but 3.9 feet in the twenty-four hours after the ice went out, and then fell gradually to the end of the month, when it again began to rise slowly, reaching the highest stage of this spring on April 15, nearly four weeks after the break-up.

In the Big Sioux river occurred the highest water since the flood of 1881. The rise began in the upper waters on March 17, and reached Sioux City and Missouri on the morning of the 20th. From Egan, S. Dak., to Sioux City, a distance of 125 miles, the area of country submerged ranged from one-half to three miles wide, the greatest width being over the flat country in the vicinity of Elk Point and Jefferson, S. Dak. The high water continued from a week to ten days. On the Rock river, which empties into the Big Sioux above Hawarden, the flood occurred on March 18 and 19, the water rising suddenly, continuing high for about one week, and then declining slowly. The overflow was one-half to one mile wide, and every bridge on that stream was either seriously damaged or entirely carried away; much damage was done to fences and to rich farm lands, which were left unfit for cultivation. At Rock Valley, Iowa, the water was several inches deep in the main street, but the damage was not very great. Every bridge on the Milwaukee railroad between Sioux City and Rock Valley was made impassable and many of them were carried away.

101. *Little Sioux river to Atchison, Kans., reported by Mr. L. A. Welsh, Local Forecast Official, Omaha, Nebr., June 18, 1897.*—During the period from March 10 to 16, the ice in the Missouri river and its branches, from the Little Sioux to the Platte, broke up and ran out. This section of the Missouri and its tributaries had been frozen over since January 23, while that portion south of the Platte to Atchison had, with the exception of a few days in the latter part of February, remained open. From the date of the breaking up of the ice to March 23, the Missouri rose steadily with a vast amount of ice running, but after the 23d it fell steadily to the end of the month. During the period from April 9 to 17 the river reached its highest stage, this rise being due to the high water in the upper river; after April 20 all danger of further flood was considered over.

From reports received since the decline of the high water, it is found that the flood conditions were greatly exaggerated by the press reports during their occurrence. There is no evidence whatever that any of the tributary branches, from the Little Sioux to Atchison, actually overflowed their banks, or that any territory adjacent thereto was submerged. From the Little Sioux to Florence lake, which is on the west bank of the Missouri, and about 6 miles above Omaha, the Missouri was not out of its banks. On Sunday, April 11, the river overflowed into Florence lake, filling the lake to such an extent as to cause it to overflow into Cut-off lake, which is located just north of Omaha and near the Missouri river. It was feared that the overflow into Cut-off lake would cause the water from the latter to overflow East Omaha. This critical condition continued from April 11 to 17, but, on the latter date, the water began to fall and all danger was past. The flowing of the Missouri into Florence lake, and thence into Cut-off lake, did no damage whatever, except that some squatters' shanties located on the river bottom were submerged for a few days, causing the occupants to move to higher and safe ground. This was practically the sum total of damage done by the spring flood at Omaha. The river bottoms, opposite Nebraska City, St. Joseph, and Atchison, were reported under water from April 12 to 18, but no damage resulted from this overflow.

102. *Atchison to the mouth, reported by Mr. P. Connor, Local Forecast Official, Kansas City, Mo., June 29, 1897.*—The Missouri river bottoms are about 2 miles wide, having more or less bluff on either side. There are two levels of bottom land, called the low and high bottoms. An overflow of the high bottoms practically includes everything from bluff to bluff. The area of low bottom land between Kansas City and Boonville is about 106,000 acres and the higher bottom, made up entirely of farming land, about 75,000 acres. The area of the high bottoms between Atchison and Kansas City is about 13,000 acres. The low places subject to the greatest overflow are in the neighborhood of Atchison and Leavenworth, at Kansas City and Sibley, from Lexington about 20 miles east, 10 miles about Malta Bend, and at Glasgow.

A great flood occurred in 1844, and, from the earliest Indian tradition to the present time, is the greatest flood in the history of the lower Missouri river. The stage reached on the present scale of river measurements was 37 feet on June 20 at Kansas City, 16 feet above the danger line. At Boonville the river reached 33.6 feet, two and a half days later, which was 13.6 feet above the danger line at that place. The flood was caused by the coincidence of unusually heavy and protracted rains with what is known as the "June rise," the melted snows from headwaters. It is said that, about the middle of April, the rains began to fall in brief showers nearly every other day. After a few weeks it began to rain every day. It poured down for days and weeks, almost without cessation. The river was rising quite rapidly, but no danger was anticipated, for the oldest settler had never seen a general and destructive overflow, and did not know that such a thing could occur. The river continued to rise, however, at the rate of 12 to 18 inches a day until June 5, when it went over its banks, and the situation became alarming. The channel was full of driftwood; occasionally a log house floated down with chickens and turkeys on the roof. In several instances men, women, and children were seen on the tops of houses floating hither and thither and turned and twisted about by heavy logs and jams, but the people were rescued by parties in skiffs.

On June 20 the water had reached its highest point, and the next day began to fall, but the damage done seemed absolute and the ruin complete. The flood extended from bluff to bluff, generally 2 miles. There was not an acre of dry land in the river bottoms, from Kansas City to the mouth of the river. The rains subsided and the river fell rapidly. A few persons moved back to their farms, in what was then a very sparsely settled region and, although it was impossible to do any farming until the latter part of July, it is reliably reported that enough corn was raised that season for the people in many places to subsist on.

Where Kansas City now stands the flood was about 3 miles wide. In what is now known as the packing house and wholesale district, where the Union depot stands and all the switching grounds are located, the water was about 10 feet deep. The flood extended over the present site of Armourdale and Argentine, in Kansas, near the mouth of the Kaw, but there were few settlements at the junction of the Missouri and Kaw in those days. A deplorable consequence of the great flood was the season of sickness which followed, and the high rate of mortality. It is said that it was impossible to find a well person on account of the miasma resulting from the decaying animal and vegetable matter. Chills and fever prevailed in their most malignant form, followed in the winter by spinal meningitis, then called "head disease," which proved very fatal. An

important fact connected with this flood was that steamboats going up the river found it as low as usual above St. Joseph, Mo. All the tributaries of the Missouri, in the state of Missouri, are believed to have overflowed their banks in 1844 very extensively, although in that early day there was scarcely anything to damage along the streams in the way of personal property.

The flood level at Kansas City was determined and marked on a pier of the Hannibal bridge, when it was being constructed, by Mr. Octave Chanute, who was supervising engineer of construction. The stage was obtained by the collation of 11 or 12 high-water marks, preserved by old settlers on both sides of the river. Mr. Chanute states that there was practical agreement in the well authenticated marks. Some years after the completion of the bridge a few local engineers expressed some doubt as to the accuracy of the stage, claiming that it was too high, but Mr. Chanute, who was then building a bridge across the Missouri at Sibley, about 30 miles east of Kansas City, found the high-water marks at that place to correspond very closely with the established mark at Kansas City, after allowing for the slope of the river. Mr. Chanute tested all data worthy of consideration in his determination, so that there is nothing upon which to base a doubt of its accuracy.

In 1897 the Missouri crossed the danger line at Kansas City on the morning o April 15, reaching its highest, 22.8 feet, on the 19th, and fell below the danger line on the 22d. Harlem, as usual, was more or less flooded. Water leaked into a number of cellars in the commercial houses in the west bottoms, rendering pumps necessary. The flood subsided until the 27th, when the Kaw rose from 4 to 5 feet in thirty-six hours, from exceptionally heavy rains in northern Kansas, where all its tributaries are located. This caused a second overflow in the west bottoms, and the powerful current cut across the Missouri to the Harlem banks, causing higher water in that village than on the 19th. Pumps were again put in operation. In Armourdale the sewers overflowed on the streets, and some of them were plugged with rock and cement to prevent further overflow. Train service from the north was much interferred with by floods at Leavenworth during the high water previous to the 19th. Tracks were nearly 2 feet under water in places, and numerous lakes were formed on the Government reservation. The flood inundated the few bottoms between Kansas City and the mouth of the river, and cut away the banks greatly in places between Kansas City and Lexington.

On April 5 the Grand went over its banks, from heavy rains in northern Missouri and southern Iowa, and it is said to have been higher than for fourteen years. The bottoms were entirely flooded, and all creeks in that section were full and overflowing. On April 28 very heavy rains in the same section caused a second rise, overflowing the low bottoms, but subsiding rapidly. Thousands of acres of good farming land in each county were inundated; miles of fences were carried away, and the land was washed very badly; in many places small lakes were left, that had not been dried up at the date of this report. The damage is estimated at nearly $1,000 to the mile. In April the Chariton river overflowed the low bottoms, but caused no damage of importance, as most crops were planted after the high water. The prime cause of all important floods in this section is heavy rains in the central Missouri basin. In occasional years, when a vast quantity of precipitation is stored in the region of headwaters during the winter months, and protracted warm weather prevails in that section in the early spring, a decided rise is looked for, but nothing of a damaging character, unless

supplemented by at least moderate rains. But with a very ordinary flow from the upper valley and heavy rains in northern Kansas, Nebraska, western Iowa, and northwest Missouri, there is sure to be a flood from Kansas City eastward.

A great number of squatters here and there along the low bottoms and on accretions of the river or neutral grounds, who indulge in farming and gardening in a small way, meet with disaster every time the least and most insignificant overflow occurs, but they do not take such lessons seriously. When the waters subside they go at it again, and, if they can secure subsistence from year to year, their ambition seems to be fulfilled. The first to be damaged by high waters at Kansas City are of this class. They have to move out with a stage of about 20 feet. At a stage of 21 feet the water begins to encroach on the low bottoms. At 22 feet it flows into the low places in Harlem, and interferes with the output of a few sewers in the west bottoms. At 23 feet Harlem is pretty well flooded, and a considerable portion of the farming lands just above the low bottoms; water leaks into cellars of commercial houses in the west bottoms; sewers become more of a menace than a utility, and in many places have to be plugged. An additional foot causes a serious situation, and floods a thousand acres of farming lands to the mile from Kansas City eastward.

The greatest damage occurs when the overflow happens late in May or in June, as it washes out all the crops, and, by the time the waters recede, it is generally too late to replant, and the condition of the soil is such that, at best, but little can be accomplished. In a great number of instances cloudbursts cause immense damage to farm and stock interests. A cloudburst near Salina, Kans., in July, 1895, along the Smoky Hill Fork, caused the stream to inundate 5,000 acres, and the damage for 40 miles along the river was greater than that of all previous overflows in that section.

Below Boonville the Missouri did not reach the danger line this spring.

THE ARKANSAS RIVER.

103. *Sources to Dodge City, Kans., reported by Mr. G. T. Todd, Observer, Dodge City, Kans., April 15, 1897.*—From Dodge City, westward, the bed of the Arkansas river has been almost dry since last July. The river was very low all through the winter and spring, and at the present time has an average width of about 10 feet, and a depth of a foot to a foot and a half. This is the usual condition of the river at this season, and there will probably be little change before the end of May.

104. *Dodge City to the southern border of Kansas, reported by Mr. F. L. Johnson, Observer, Wichita, Kans., June 20, 1897.*—In Kansas the Arkansas river is a broad, shallow stream, swift when up, but frequently dry for months at a time. About the only time it is high is when the heavy rains of May and June and the melting snow in the mountains of Colorado cause the high water locally known as the "June rise." This usually occurs during the first decade of June, and the rise lasts from five to ten days. It comes suddenly and subsides slowly, and is usually confined to the Arkansas river, the tributaries being exempt. Although this rise comes suddenly, it does not come unexpectedly; it requires about five days for the rise to reach Wichita from Colorado, three from Dodge City, and one from Hutchinson. It takes from ten to fourteen days for a sudden rise of water at Wichita to reach Fort Smith. Irrigating ditches in the western part of Kansas take considerable water from the river. In prolonged dry periods all the water sinks into the sandy bed of the stream before reaching Hutchinson.

From Hutchinson to Wichita the river bed is, in dry times, a waste of drifting sand; but at Wichita the tributary stream, Little Arkansas river, which never goes entirely dry, adding its small contribution, makes the Arkansas river, from there on, a stream in fact as well as in name, except in extraordinarily prolonged drouths, when only occasional pools remain.

The bottom lands along the Arkansas river vary in width from 1 to 3 miles, and the river banks are from 6 to 10 feet high, as far south as Wichita. South of Wichita the banks are higher, on the left bank considerably higher, and the bottom lands narrower. The principal tributaries are the Pawnee at Larned, the Little Arkansas at Wichita, the Ninnescah, 35 miles south of Wichita, and the Walnut at Arkansas City, Kans. The slope of the land is east or southeast and quite marked, so that the streams are generally rapid. By reason of the almost impervious sod that covered the virgin prairie, the greater part of the heavy rains flowed at once into the streams. As more and more of the prairie sod is broken, and many little runs are dammed to make ponds, less and less water flows into the stream; so that now their beds are usually broad and deep enough to hold even the flood waters. In Sedgwick county the proportion of broken land to the whole surface is about one-third. The percentage of broken land decreases westward. The importance of this change in the land surface on the frequency of floods is scarcely appreciated. Before the land is broken the water runs off the virgin sod almost as from the roof of a house; after the sod is broken and the land cultivated for a few years the soil absorbs water with the avidity of a sponge.

There has been no flood in the Arkansas this spring; in fact the usual June rise has failed, so far, to come. There is but one flood recorded at Wichita which deserves mention; after a heavy rain for nine hours on May 17 or 18, 1877, there followed two days of clear weather, and then about the 20th a heavy rain fell for fourteen hours. The water in the Arkansas was up and the river had been bank-full for several days. On May 21, 1877, the water of the Little Arkansas river, unable to discharge into the Arkansas, began to overflow its banks at Pine street, and ran down through the town, flooding the first floor of the Occidental hotel at the corner of Main and Second streets. The water was highest on the 22d, and began to recede on the 23d. The flooding of the town was due to water from the Little Arkansas only. Here in town the "Big" river merely refilled to a depth of about 3 feet a low tract about 300 feet wide, that had once been a part of its channel. Three or four miles south of town, the flood spread out over the valley from 3 to 5 miles, and so continued for about 12 miles down, the overflow being almost wholly on the right bank. The damage, aside from the inconvenience, appears to have been small.

105. *Southern border of Kansas to Dardanelle, Ark., reported by Mr. J. J. O'Donnell, Observer, Fort Smith, Ark., June 20, 1897.*—There has been no flood in the Arkansas river this year between the southern line of the state of Kansas and the mouth of the Verdigris river, 141 miles west of Fort Smith. Floods or overflows are rare in this portion of the Arkansas river, and its principal tributaries in this reach, the Salt Fork and Cimarron rivers. The Salt Fork has never overflowed. The extraordinary rain and reported cloudburst in April, 1897, in the vicinity of Guthrie, and in the valley of Cottonwood creek, resulted in floods and overflows at many places between Guthrie and the mouth of the Cimarron river. From the mouth of the Verdigris river to Fort Smith several large rivers empty into the Arkansas, and eastward to Dar-

danelle many creeks of considerable importance. Along this reach of the river overflows and floods are quite frequent, occasionally doing great damage to crops, railroad property, stock, and lumber. The banks have been overflowed, except between Piney and Dardanelle on the north bank, between Patterson's bluff and Morrison's bluff on the south bank, and between Redland and Wilson's rock.

106. *Dardanelle to the mouth, reported by Mr. F. H. Clarke, Local Forecast Official, Little Rock, Ark., June 20, 1897.*—The Opossum Fork levee in Desha county runs to high land on Amos Bayou ridge, but the flood of 1897 passed over the ridge, above the levee, and there was also a small break in the levee, 3 miles from the upper end. The Arkansas river levee stops at a point nearly opposite the head of the Opossum Fork levee, and leaves a space of about 10 miles, which is not protected by levee, and the water backs up to a point near Watson. There was no flood in the Arkansas river during 1897, and no breaks in the levee. All the water that flooded Arkansas territory came from the Mississippi.

THE RED RIVER.

107. *The Red river, reported by Mr. Chas. Davis, Observer, Shreveport, La., June 16, 1897.*—Copious and well distributed rains having fallen throughout the valley of the Red river, an exceptionally long period of very low water was terminated during the first days of January, 1897, and, while there were decreasing stages during February, the stream, for the most part, continued navigable until heavy rains in March gave a rapidly rising river, which, in the opinion of many, betokened a disastrous overflow. This opinion proved to have been erroneous, as the highest stage at Fulton was only 0.6 foot above the danger line (28 feet), while Shreveport's maximum reading was 5 feet below the danger line (29 feet). Although the readings in some instances were slightly above the point at which danger begins, farm work did not suffer interruption, and the spring of 1897 will be remembered as a very favorable one for those engaged in both river and agricultural pursuits along the Red river.

THE LOWER MISSISSIPPI RIVER.

108. *St. Louis, Mo., to Chester, Ill., reported by Mr. H. C. Frankenfield, Local Forecast Official, St. Louis, Mo., May 20, 1897.*—In the city of St. Louis there was no overflow, and no damage was done except a very little by seep water. In places along the levee the railroad tracks were covered, but no inconvenience resulted. Opposite the city, in Illinois, the water reached the town of West Venice, running through some of the streets on April 10, and also flooded a couple of farms. The lowlands back of East St. Louis, Ill., were also overflowed by the backwater through Cahokia creek, and some portions of the village of East Carondelet, Ill., were submerged on April 11, but the damage was very slight. From St. Louis to Chester there was no flood worthy of mention, perhaps 1,500 acres of low bottom lands being overflowed during the first half of April.

109. *Chester to New Madrid, Mo., reported by Mr. P. H. Smyth, Observer, Cairo, Ill., May 29, 1897.*—From Chester to Cairo, Ill., only the very lowest bottoms were flooded, and very little damage resulted. At Cairo the levees kept in good condition throughout the flood. Seep water, augmented by rains and waste water, gradually

increased from about the middle of February, and by the end of March had risen to within 10 inches of the sidewalks of the graded streets. The maximum height of the seep water was reached on April 13. Nearly all of the graded streets were covered, or partly covered, and on many of the streets the sidewalks were several inches under water. Over 50 houses, located in the lower portions of the town, had to be vacated on account of water being in them, and there were as many more that were badly flooded, but were occupied. This state of affairs lasted for over a month. The authorities had put in operation two drainage pumps to relieve the city of the water, and after the pumps got to working the seep water was very materially reduced. All the ungraded portions of Cairo were flooded from the latter part of February until the middle of May, and in some of the lower bottoms the seep water remained until May 25. During the prevalence of seep water one old man and two children were drowned.

The flood of 1897 at Cairo, Ill.

From Cairo to New Madrid, Mo., both banks of the river were submerged, except where the levees held, and even then the backwater from the breaks covered the country. At Columbus, Ky., the river lacked 4 inches of being as high as in 1883, and at Hickman, Ky., the flood of this spring was not as great as the floods of 1882, 1883, and 1884, although about the same area in Fulton county has been submerged. Washouts occurred on the Iron Mountain railroad on March 19, causing damage to the extent of about $50,000. On the west side of the river about five-sixths of Mississippi county was submerged, and about one-half of New Madrid county. Birds Point, Mo., was completely overflowed and practically abandoned during the flood. Many thousands of acres of wheat in Mississippi county were drowned out and ruined. At Belmont, Mo., the river reached a stage one-half inch higher than ever known before.

110. *New Madrid to Helena, Ark., reported by Mr. S. C. Emery, Observer, Memphis, Tenn., May 13, 1897.*—The beginning of the flood in this section dates from February 8. For ten days preceding that date a rapid decline had been in progress, and on February 7 the low stage of 8 feet was recorded on the Memphis gauge. A rapid rise then set in, which continued up to the 20th, when the stage was 25.1 feet. This flood wave came from the upper Ohio river, the crest passing Cincinnati on February 11, with a 44.4-foot stage, and reaching Cairo on the 17th, with a gauge reading of 34.7 feet, a rise of 20 feet in twelve days. At Memphis the wave was thirteen days in reaching its highest point, the rise amounting to 17.1 feet. The highest water was reached at Helena on the 21st, the gauge reading 33.2 feet, and the height of the flood wave was 18.7 feet, which was reached after a rise covering a period of twelve days.

It will be noted that the crest of this wave was exactly ten days in passing from Cincinnati to Helena, and, except a slight depression at Memphis, the same height was maintained throughout the entire distance, and the same number of days intervened between the first rise and the point of decline. While the flood wave noted above was in progress, a second and more extensive one was moving down the Ohio, receiving on its way heavy additions from the Cumberland and Tennessee rivers, which were raised to flood height by heavy rains throughout the region drained by them. All of the above rivers began to rise simultaneously, and with great rapidity. Meanwhile, rains throughout the valleys of the Lower Mississippi and the Ohio continued with increased frequency and volume. The last great flood wave was first felt at New Madrid on February 24, and at Memphis on February 26, after a very slight fall from the preceding one. For one week the rise over this section of the river averaged about 1 foot per day, and afterward from 0.4 to 0.6 foot daily.

By March 6 the lowlands about Memphis were under water, and the water began to flow over the banks on the Arkansas shore. At 7 a. m., March 9, the stage at Memphis was 32.9 feet, and at 11 a. m. of that day the danger line had been reached. At this time the greatest excitement prevailed in this section; people occupying the lowlands were moving out, and large sums were being expended in the protection of property against an overflow, which now seemed imminent. Hundreds of men were set to work on the levees, as upon their stability depended the fate of the entire St. Francis basin. On March 12 the town of Hopefield, Ark., opposite Memphis, was submerged, and most property was removed to places of safety. The 13th of March was an eventful day in this section. On that day, Marion, the county seat of Crittenden county, Ark., and the adjacent land for 3 miles from the river was flooded. There were in Marion 500 people who resided there, and as many more who had been driven there by the high water in the bottoms. This place was formerly a city of refuge for people in that section on account of the dike around it, which had withstood all previous floods, and was built several inches above the previous high-water mark, but, at about 8 p. m. on the 13th, the water began to pour over the lower places in the dike, and in a short time there were from 4 to 6 feet of water over the entire town. On the first floor of the courthouse the water stood 18 inches deep, and there was scarcely a habitable house in town. On the same day, about 7 p. m., 300 feet of the old state levee at Butler's plantation, 4 miles north of Nodena, Ark., gave way. The break was 15 feet deep, and in a very short time the whole country about Nodena was covered to such an extent that the people were obliged to abandon their homes, and seek safety on

the embankments, or whatever elevations could be found. In many instances it was found impossible to save even the stock, which was left to perish.

By March 16 the entire territory between Memphis and Crowleys ridge, which is 40 miles west of the river, was under water, and the work of rescuing the people was going on day and night. From every direction came reports of unexpected and unprecedented disaster. Localities that were expected, up to the last moment, to withstand the overflow, were at last under water, and the people found themselves hemmed in with no means of escape, and all they could do was to await, frequently on the roofs of their dwellings, the coming of the rescuing boats. At Marion, 400 people were found lined up on the railroad embankment, over which an occasional wave swept; and along the railroad lines, as far as the relief boats could penetrate, the same condition of affairs existed. Men, women, and children, and stock, were found, chilled by the cold, and standing in water, ranging from foot to neck deep.

On March 17 a break occurred in the levee at Caruthersville, Mo., which soon became 700 feet wide, and sent a vast body of water down toward Mississippi county, Ark. Another break occurred, 18 miles south of Caruthersville. The town of Osceola, Ark., 100 miles north of Memphis, was covered to a depth of about 3 feet, and opposite, in Tennessee, the water extended 15 miles inland. The town of Golddust had from 3 to 4 feet of water in its streets. Ashport was also badly flooded.

By March 18 the situation was extremely critical; the river at New Madrid was then nearly 1 foot above the highest known stage; at Memphis it had reached a point 3.8 feet above danger line, the gauge on that day reading 36.8 feet, a rise of 9.5 feet since March 1. Five breaks had occurred in the levee near Nodena; in fact, about 2½ miles of the old levee at that place had been swept away. The most serious break was the one at Sans Souci, which occurred during the afternoon of the 19th. For two weeks the citizens of Sans Souci had been working day and night to keep the water outside the levee, a break in which meant the devastation of the country below. The strain on the levee finally became too great, and a break occurred, through which the water rushed with tremendous velocity, and, though every effort was made to close up the crevasse, it steadily widened, and the whole country back of Sans Souci was soon flooded.

This break, and the general downfall of the old state levee near Nodena, caused the river at Memphis to come to a stand at 37.1 feet on the morning of March 19. On the same day the gauge at Memphis was carried away by the flood, and it was found necessary to use the old gauge, located about a half mile north of the one destroyed. This old gauge was found to read 0.6 foot higher than the one formerly used, and, in order to make the readings harmonize with those previously taken, this amount was deducted from the actual readings from and after the 19th. This stage continued at Memphis for three days, when the river began to decline, but so slowly that, after thirty-three days, the decrease only amounted to 2 feet. Had the levees above remained whole, it is likely that at least another foot would have been added to the Memphis record, as the rise continued at New Madrid up to the 29th, or ten days after the maximum height had been reached at Memphis.

At the beginning of the flood the current in the river was very rapid, estimated at 8 to 10 miles per hour, but, as the country below became filled, the velocity of the current decreased to half as much. The water which left the main river through the

numerous crevasses and passed through the St. Francis returned at Helena, which accounts for the continued rise at that place after the fall had set in at Memphis. From March 19 to 25 the St. Francis bottom and the lowlands along the Tennessee shore filled rapidly, and the maximum height of the water over the flooded territory was reached by the 25th. On the Tennessee side the water extended farther inland than it was ever known to do during any previous overflow; in Dyer county the water covered a large tract of rich farm land, which heretofore had been considered above the possibility of an overflow.

By March 31 the flood had completed its work of destruction over all the territory from Memphis northward, and the waters were slowly receding. South of Memphis, in the vicinity of Helena, the situation was still extremely critical, and every possible effort was made to meet the impending crisis. On Sunday, April 4, the first break in the Yazoo levee system occurred at Flower lake, opposite the mouth of the St. Francis river, and on the farm of Mr. F. M. Norfleet. The break occurred at 7.30 a. m., and, by 11 a. m., it had grown from a few feet to 500 feet in width, and two days later the crevasse was 2,000 feet wide. Through this gap a mighty river was emptying itself on to some of the richest cotton lands in the state, and soon the southeast portion of Tunica county was flooded. This crevasse completed the destruction in this section, and the river at Helena fell from that time on.

The Mississippi in flood near Greenville, Miss.

The money value of the property destroyed can not be estimated at this time, but it will amount to a very large sum. The heaviest sufferers from the overflow are those engaged in farming, and owners of farm lands upon which small tenants, occupying frail dwellings, had been established. These dwellings have in many cases been washed away, and a large number of those remaining are beyond repair. Fences are washed away; farm implements and seed destroyed; and live stock drowned in great

numbers. Those who could do so, drove their stock to mounds and ridges, where such were available, and others built rafts upon which cattle and hogs were kept until the water subsided, or they were removed to places of safety. In many places, however, the flood came so suddenly and unexpectedly, that there was no time to save anything but human life, and cattle were left to drown. Many of the cattle and horses, collected on mounds and other high places, were killed by the dreaded buffalo gnats, which are one of the usual results of an overflow in this section. Another item of damage to farm property is the deposit of sand, which in some cases is several feet deep, and renders the land unfit for cultivation. The damage to railroad property throughout the St. Francis basin and the Delta country is very great. Several railroads leading out of Memphis were kept in operation by building a false structure, from 1 to 2 feet high, above the track, and placing rails upon this for the passage of trains.

Of the previous overflows, that of 1882 is considered, in this section, to have been the greatest, and all comparisons are made with that flood. In that year the water extended over a greater area in the northern portion of the St. Francis basin, and to a greater depth than during the present overflow, as the levees kept out a great amount of water this year from that section. The opposite side of the river, in Tennessee, throughout the counties of Obion, Lake, and Dyer, which had no levee protection, received the water which formerly went into the St. Francis, and, as a consequence, those sections were flooded many miles farther inland than ever before. That portion of Arkansas extending from Mississippi county south was covered to a greater depth than in 1882, or any previous year, and the depth increased as one traveled southward, until the high ground near Helena was reached. A farther spreading westward was prevented by Crowleys ridge. That portion of the St. Francis basin where the inundation was practically complete is comprised within the following area: The whole of Crittenden and Mississippi counties, about half of St. Francis and Poinsett, and nearly all of Lee counties. This section was flooded to a depth of from 3 to 7 feet. The population of the five counties named is 45,000, of which 25,000 are blacks. Over 200,000 acres of land are tilled in this area, of which 90,000 are devoted to cotton, the remainder being about equally divided between corn and potatoes. Crittenden and Mississippi counties have 40,000 acres of cotton land, and produce about 30,000 bales of cotton annually.

111. *Effect of the St. Francis levee.*—Before comparisons can be made between the present flood and those which have occurred in former years, it is necessary to take into account the changed conditions which have resulted from the construction of the Arkansas levees. Since 1890 there has been built a line of levee along the west bank of the Mississippi river, extending from Point Pleasant, Mo., south to Pecan point, a distance of 125 miles. The purpose of the levee is to protect the St. Francis bottom, the greater portion of which was formerly subject to an annual overflow. Of this bottom much is not under cultivation, considerable areas being covered by a succession of swamps and lakes having a heavy growth of gum, sycamore, and cypress trees. In former years the bottom had been flooded more or less whenever the Mississippi, at Cairo, reached a 41 or 42-foot stage. The water, after leaving the main river, passed into the St. Francis basin, through which runs the Little and St. Francis rivers; through these channels it again found its way to the Mississippi at a point about 12 miles north of Helena, Ark. The effect of leveeing the west bank of the Mississippi,

in front of the St. Francis bottom, is to compel the water to pass down the Mississippi, from Cairo to Helena.

In the following table a comparison is made of several earlier floods with that of this year. The floods occurring from 1882 to 1886 reached about the same stage at Cairo as the flood of this year. The maximum stages at Cairo, Fulton, Memphis, and Helena, during the floods of 1882–86, together with their mean, and the corresponding stages of this year's flood, are presented.

Year.	Cairo, Ill.	Fulton, Mo.		Memphis, Tenn.		Helena, Ark.	
	Maximum stage.	Maximum stage.	Below stage at Cairo.	Maximum stage.	Below stage at Cairo.	Maximum stage.	Below stage at Cairo.
1882	51.8	36.7	15.1	35.0	16.8	47.2	4.6
1883	52.2	36.3	15.9	34.8	17.4	46.9	5.3
1884	51.8	35.7	16.1	34.2	17.6	47.0	4.8
1886	51.0	35.4	15.6	34.8	16.2	48.1	2.9
Mean	51.7	36.0	15.7	34.7	17.0	47.3	4.4
1897	51.6	37.4	14.2	37.1	14.5	51.5	0.1

The average difference in stage, in the earlier floods, between Cairo and Fulton was 15.7 feet; between Cairo and Memphis, 17.0 feet; and between Cairo and Helena, 4.4 feet. The building of the levee has caused a decrease in the difference between those points; that is, it has raised the stage at Memphis about 2.5 feet above what it would have been, had the water been left to flow over the lowlands of Arkansas. So, instead of a difference of 17.0 feet between the Cairo and Memphis stages, we now have about 14.5 feet, and, had it not been for the breaking of the levee, it is probable that this difference would have been lessened at least an additional foot. In other words, the levees, if kept intact, would result in some 3 feet more water at Memphis than under former conditions. At Helena, the change is still more marked, and the former difference of 4 feet has entirely disappeared, and, had it not been for the great crevasse at Flower lake, the Helena flood crest would probably have been considerably above that at Cairo.

112. *Helena to Vicksburg, Miss., reported by Mr. R. J. Hyatt, Local Forecast Official, Vicksburg, Miss., July 2, 1897.*—At all points in this section the Mississippi was below the danger line on March 1, but the high water above Memphis and the high stage of the Ohio were viewed with concern by the people along the Lower Mississippi. Timely warnings that the river would reach danger-line stages and above, were promptly issued and widely circulated, in order that due preparation might be made for the coming flood waters. These warnings were heeded by many, and no complaint in regard to them has been heard on any side. The planters, cattle raisers, levee boards, railroads, river men, and other interested parties, went to work in earnest to arrange for the high water in sight, and for a probable overflow of the lowlands in this section. These warnings were kept up during the month, and were supplemented by warnings from the Washington office, with good effect.

The flood proved to be the most disastrous on record. The people commenced

early to move their stock and other movable property to places of safety. Some, however, waited until the last minute before moving, depending on the stability of the levees, and, consequently, much valuable stock and other property were lost, which might have been saved had the warnings been heeded earlier. The crops, of course, were ruined by the overflow, but nearly all of the land was replanted as the water receded. Railroad communication was interrupted, and many points were only accessible by boat. Happily no lives were lost, although there were many narrow escapes from drowning, and much personal inconvenience and suffering were experienced by all. The greater portion of the levees remained intact, and a number of mounds and scattered strips of land were not overflowed. Upon these the people took refuge, with their stock and household effects, while a large number of people were quartered in the cities and towns not overflowed, living in tents furnished by the Government, and forming camps, where they were supplied with food and clothing until the land was uncovered. The deposit left by the flood has enriched the land, and cotton and corn, planted as the water subsided, have done well.

113. *Vicksburg to the mouth, reported by Mr. R. E. Kerkam, Local Forecast Official, New Orleans, La., June 18, 1897.*—The rapid rise to past the danger line, at Cairo, early in March, combined with the heavy rains, that fell over the Central Valley during the middle of March, was a premonition of the coming high waters. Warnings were issued, during the middle of March, to threatened districts in northern Louisiana, and the press of the state was served with special warnings and bulletins, proclaiming the coming of a disastrous flood wave. All methods of dissemination of the warnings were utilized, the telegraph and telephone lines, the mails, and the press, and it is a safe assertion that there was no intelligent person in the threatened district who was not fully alive to the existing danger. The fact that the levees had been strengthened and raised some 3 feet above the highest previous known waters, gave a certain confidence to many who could scarce credit the extent of the coming flood, but the reiteration of the warnings of the Weather Bureau, day by day, resulted in general work on the levees, strenghtening and raising them to hold the stage forecast.

The first crevasse of the season occurred on bayou La Fourche, near Raceland, on March 30, but the damage was only local. On April 2, a second crevasse occurred on bayou La Fourche, 4 miles below Lockport, entailing some loss to the plantations in the vicinity, but no damage of serious consequence, owing to the fact that no great area in that section was in cultivation. The third and most serious break on bayou La Fourche occurred April 16, 1 mile below La Fourche Crossing, flooding more cultivable land than either of the other two. The waters from the crevasses overflowed a considerable area of triangular shape extending from Thibodeaux southward, over adjoining portions of Terre Bonne and La Fourche parishes to the Gulf.

The first break along the Mississippi, below Vicksburg, occurred in the private levee surrounding Davis island. The island has an area of 5,000 acres, and a population of nearly 2,500, mostly negroes. The entire island was submerged, but all stock was removed, and there was little loss of property and no lives. At 10 p. m., April 16, a break occurred in the Biggs levee on the Louisiana side, 4 miles below Delta. This was the first break in the Louisiana line on the Mississippi. It widened with such great rapidity that all attempt at closing it was out of the question, and in four hours it was 1,000 feet wide and cutting very fast. The engineers' measurement of this

crevasse, on April 23, gave the width as 2,200 feet, a depth averaging 16 feet, and a current of 5 miles per hour.

The Biggs crevasse, 4 miles below Delta, La.

On April 19, a break occurred in the Reid levee, 1½ mile below the Biggs. This crevasse widened to about 600 feet, with a depth of 16 feet. The Glasscock levee, 20 miles below Natchez, on the Louisiana side, also broke on the same day. On the next day this break had reached a width of 1,000 feet, after which but little cutting occurred. These breaks flooded nearly all of Madison, Tensas, and Concordia parishes, and, by the last of April, had filled the basin at the head of the Atchafalaya, and threatened the portions of the state lying to the southward. A small break occurred at Paulin J. Coco's place on bayou des Glaizes on April 29, but was soon closed.

From April 24 to May 12 a series of breaks occurred in the levee at Burton's saw-mill, in the lower portion of Baton Rouge. The first break, on April 24, was 20 feet wide. Material and men being right at hand, the break was soon closed, and the damage was confined to the yard of the mill. On May 8 another break occurred in the same stretch of levee, but was soon repaired, before doing serious damage. On the 10th, the third break, 60 feet wide and 4 feet deep, occurred at 1 a. m., but the ends were secured. This was followed on the 11th by another break. Work was begun on a box levee around the whole stretch, and the water was confined by the night of the 11th. On the 12th, the fifth and last break occurred, under the dry-kiln of the mill, which stood across the line. This proved to be the most serious of all, and was not closed until the mud box was completed on the 20th. During the time of these breaks, the lower portion of the city of Baton Rouge, known as Catfish town, was flooded with water to a depth, varying from a few inches to several feet; but little damage was done to the surrounding plantations, as the water readily found its way to bayou Manchac, and was carried off.

Another series of breaks, three in number, occurred below the city of New Orleans

on April 26, 27, and 29. The first, on Melrose plantation, on the west bank of the Mississippi, 9 miles below Scola's canal, and 49 miles below New Orleans, occurred at 10:30 p. m. of April 26; its width was 35 feet and depth 4 feet. At 1 a. m. of the 27th, a break, 50 feet wide and 6 feet deep, occurred on the Gucanard place, near Nairn. Both breaks were closed on the 27th. On April 29, the third break occurred on the place of Mr. Charles Bally, near Home Place, and was closed at a late hour that night. The damage from these breaks was only local, and confined mostly to submerged truck farms, in their immediate vicinity.

On May 2 a break occurred in the private levee surrounding the Angola plantation of 6,000 acres, opposite the mouth of Red river. The overflow was confined to this plantation, which was completely submerged. Little loss occurred, however, as all stock that was not needed in working the levee had been removed, and there was little difficulty in taking off in safety what was left on the plantation.

On May 9 four breaks occurred on bayou des Glaizes, in what is known as the Ten Mile levee, at Longmire's, 2 miles above Hamburg. It opened to a width of 100 feet, and a depth of 5 feet. An attempt was made on the next day to close it, and, by May 12, the cribbing was all in, and the break confined to 80 feet; it was then abandoned on account of the dirt being under water, and the labor too great to bring it from a long distance by boat. The second break occurred at Paulin J. Coco's, 3 miles above Hamburg; the width was 600 feet and the depth 2 to 3 feet. Two breaks, both small, occurred at Mrs. Bruilty's, 4 miles above Hamburg. Owing to lack of material, no effective attempt could be made to close them, and the breaks merged into one crevasse, aggregating 2,800 feet in length on May 23.

The banks of bayou des Glaizes, being high, were not leveed until recently, when the encroaching waters, inclosed by levees elsewhere, reached unprecedented heights and the residents constructed small levees to withhold the water as it rose. The general opinion is that these breaks overflowed a great area of country. In reality the engineer detailed to report the amount of ground covered ascertained that the water from these crevasses flooded the large loop of the bayou, and the western bank of bayou des Glaizes and the Atchafalaya river down to about Melville, and extended inland from a few hundred feet to a mile or so. While a large portion of this section was under water, it did not come from the breaks, but was backwater from the numerous small bayous and creeks, which always overflow when it rains. Rain fell intermittently, but in considerable amounts, in this vicinity, from May 8 to 13, softening the levees; and the rain, with the windstorm of the 9th, was the direct cause of the breaks just described.

The last crevasse of the flood occurred on May 30, at Conrad Point, 8 miles by river below the city of Baton Rouge. This break opened to a width of 240 feet, and a depth ranging from 13 to 17 feet. The water flooded the portion of East Baton Rouge parish between the river and the hills, from 5 miles above the crevasse to bayou Manchac below. Owing to the high velocity of the current, and the narrow batture in front of the break, the chances of closing it were slight, but, by hard work, a well organized force succeeded in building a crib around the entire opening, and closing it by the night of June 7.

In point of area overflowed and damage done, the flood of 1897 will not compare with that of 1882 or 1890. The area, this year, is similar to that of 1892, except that

no breaks occurred along the east bank from Ascension parish to below New Orleans, while the lower portion of the La Fourche basin was overflowed this year but was not in 1892. The area is greater than that of 1893.

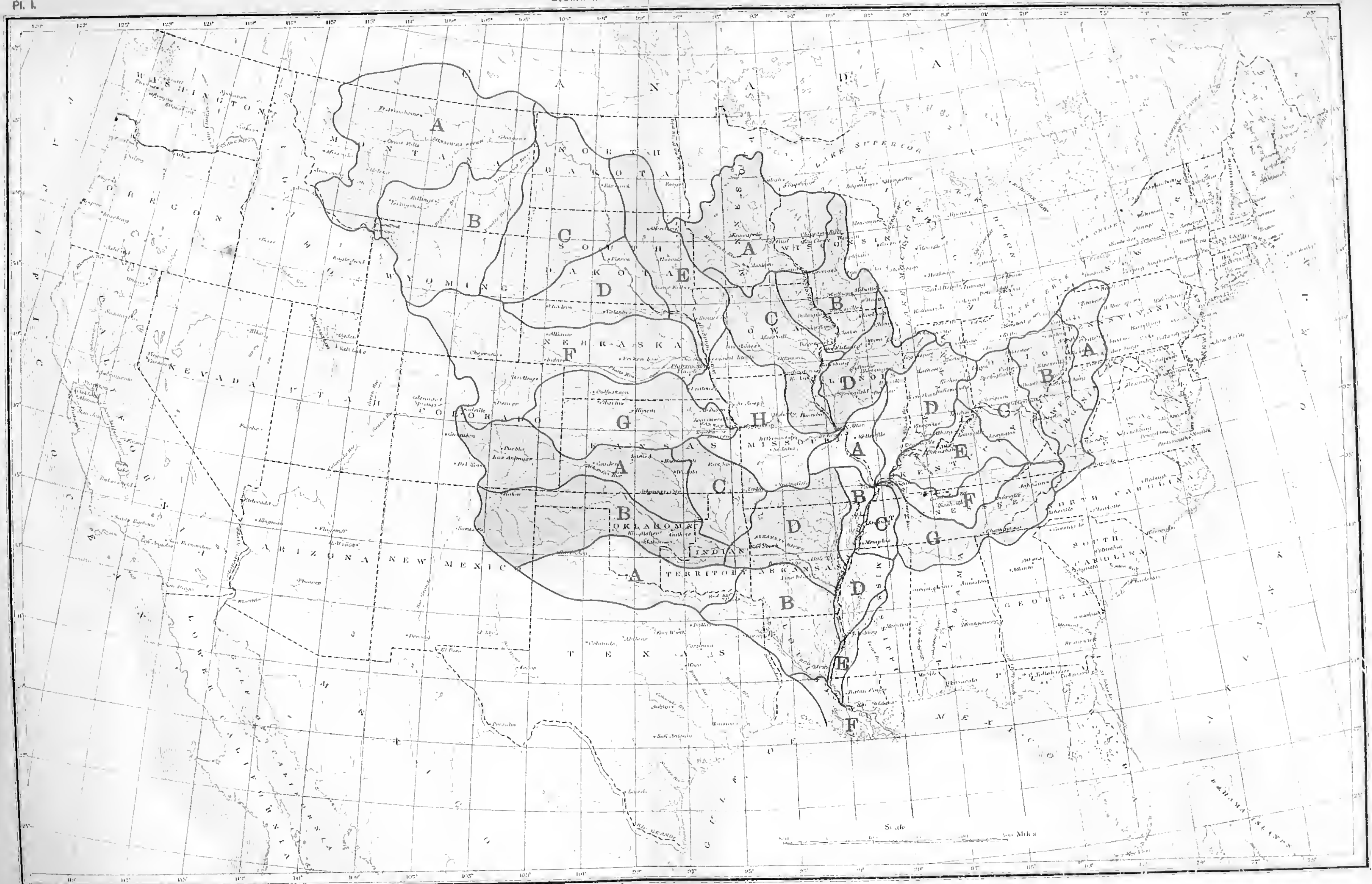
The loss of stock was comparatively small, as the planters had timely warning, and made preparations for saving their stock, when overflow became imminent. The loss of poultry, considerable quantities of feed, farming implements, and hogs, was perhaps greater than that of other properties. Many planters had seed in the ground, while others delayed planting as much as possible, fearing loss of their seed and labor by overflow. The losses of first planting were considerable, but the rapid decline in the river and backwater, permitted considerable replanting early in June, and the loss of staple crops, cotton and corn, will be reduced to the minimum by the favorable growing weather for the late seeded crops. In the bayou La Fourche district, the few plantations, situated immediately on the banks of that stream, suffered almost complete destruction of cane plantings and stubble. Loss of life was reported in many cases, but further investigations proved the rumors to be without foundation, and no case is at present known of loss of life due to the overflow.

In order to better study the flood and follow its crest, special river-gauge readings were received from Natchez, Miss., Bayou Sara, La., and Donaldsonville, La., from March 25 to June 15. These readings show that the river passed the danger line at Natchez on March 26, reaching the highest record of 49.8 feet on March 29, at which point it remained until May 3. The decline then began, the water receding below the danger line on June 4. At Bayou Sara the river was above the established danger line of 28 feet during the entire time reports were received. The highest stage at that point was 43.8 feet on May 14 and 15. Donaldsonville reported stages above the danger line from the first report, on March 25, to June 12; the highest stage was 32.8 feet on May 13 to 17.

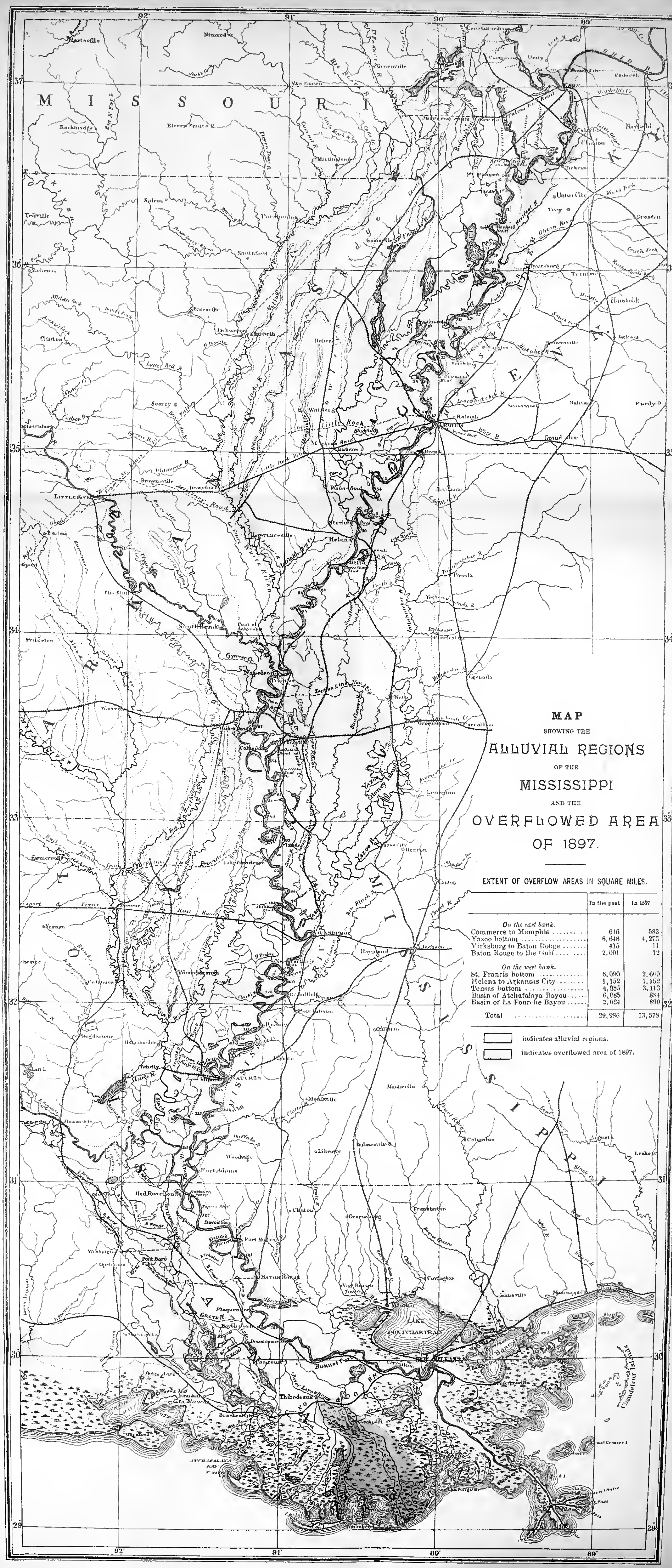
At New Orleans readings were taken at 8 a. m. and 8 p. m. during the dangerous stages. The danger line of 16 feet was reached March 27, with a steady rise to May 8, when the stage at 8 p. m. was 19.6 feet. Slight fluctuations occurred on the succeeding three days, and 19.6 feet was again recorded at the evening observations on the the 9th and 11th. On the 13th, the highest morning reading, 19.5 feet, was recorded, and it could not be said that the river showed an actual decline until after this date, as it is probable that its stages were slightly influenced by wind and tide, causing slightly higher readings, as a rule, in the evening. The river again fell to the danger line June 9.

Pl. I.

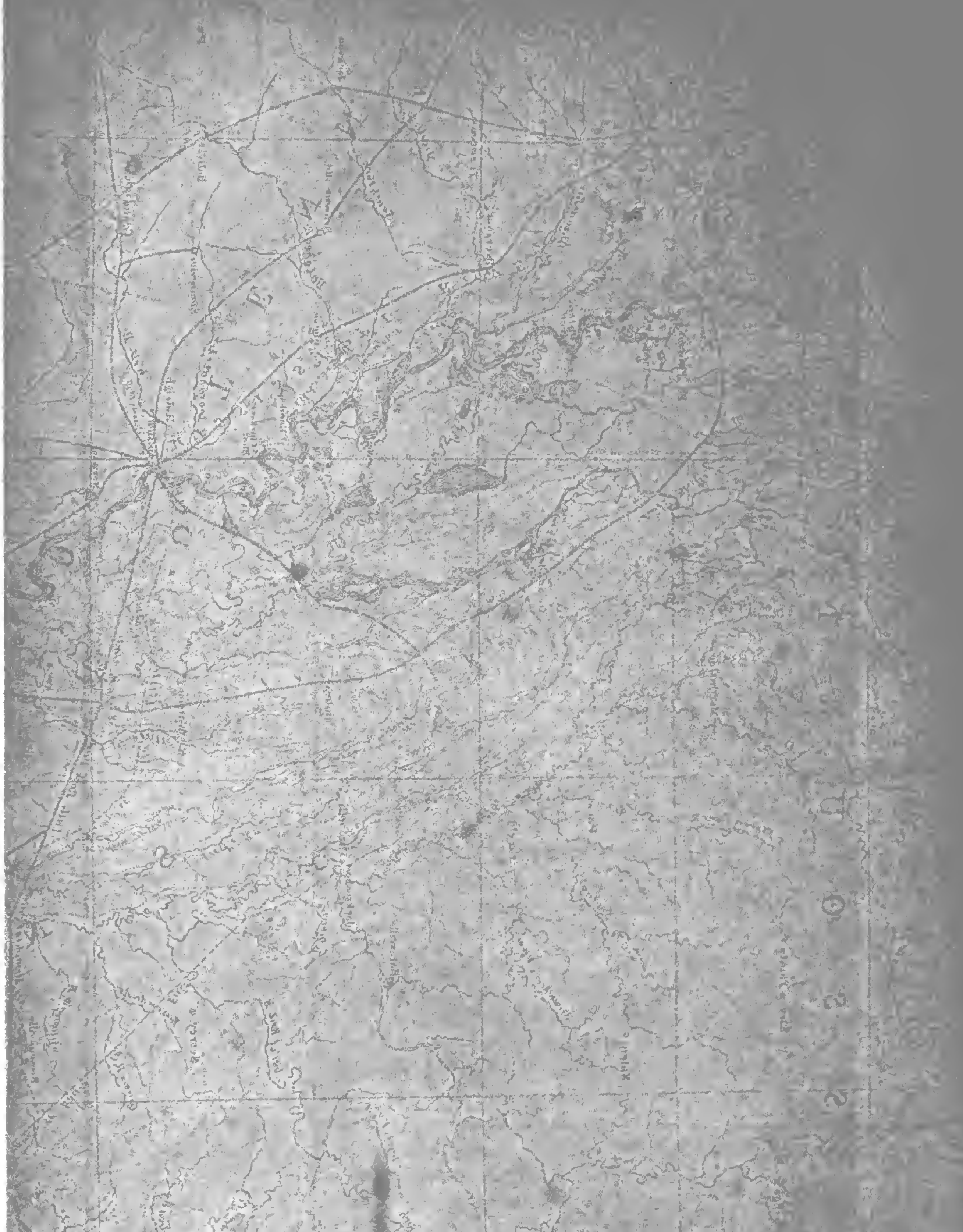
DRAINAGE BASIN OF THE MISSISSIPPI RIVER



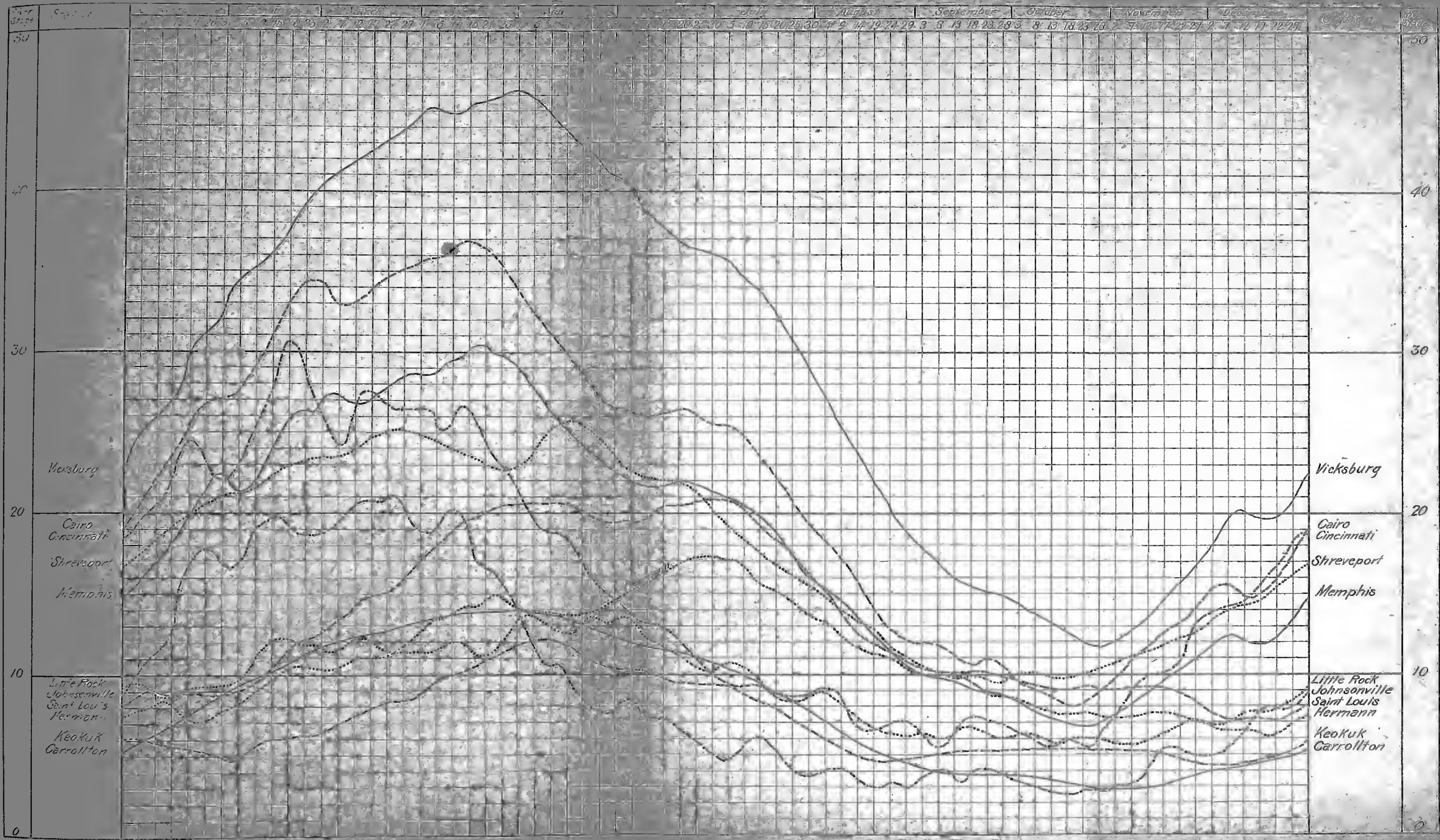
Pl. II.



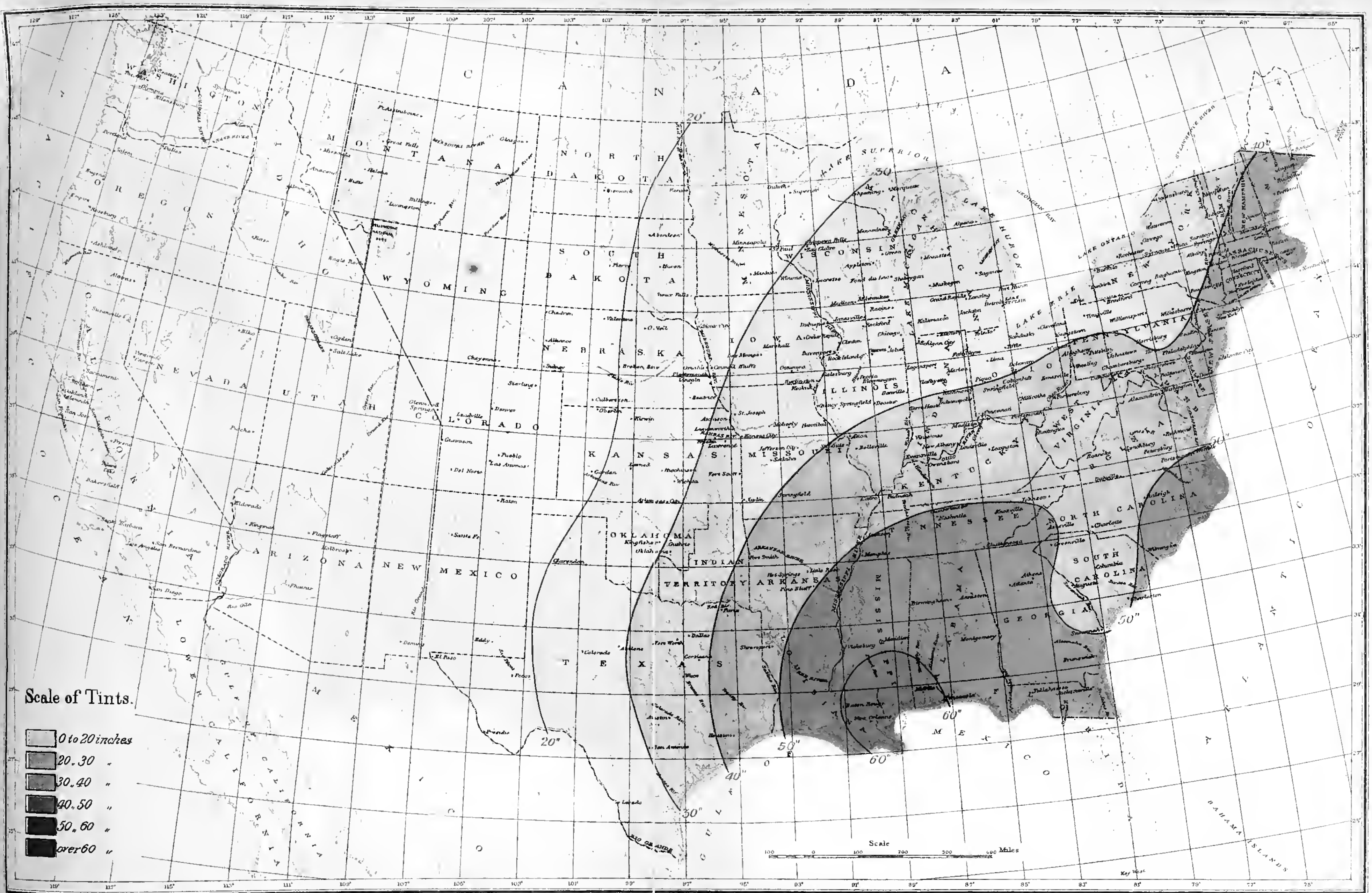
	In the past	In 1897
On the east bank.		
Commerce to Memphis	616	583
Yazoo bottom	6,648	4,273
Vicksburg to Baton Rouge	415	11
Baton Rouge to the Gulf	2,001	12
On the west bank.		
St. Francis bottom	6,090	2,660
Helena to Arkansas City	1,152	1,152
Tensas bottom	4,955	3,113
Basin of Atchafalaya Bayou	6,085	884
Basin of La Fourche Bayou	2,024	890
Total	29,986	13,578

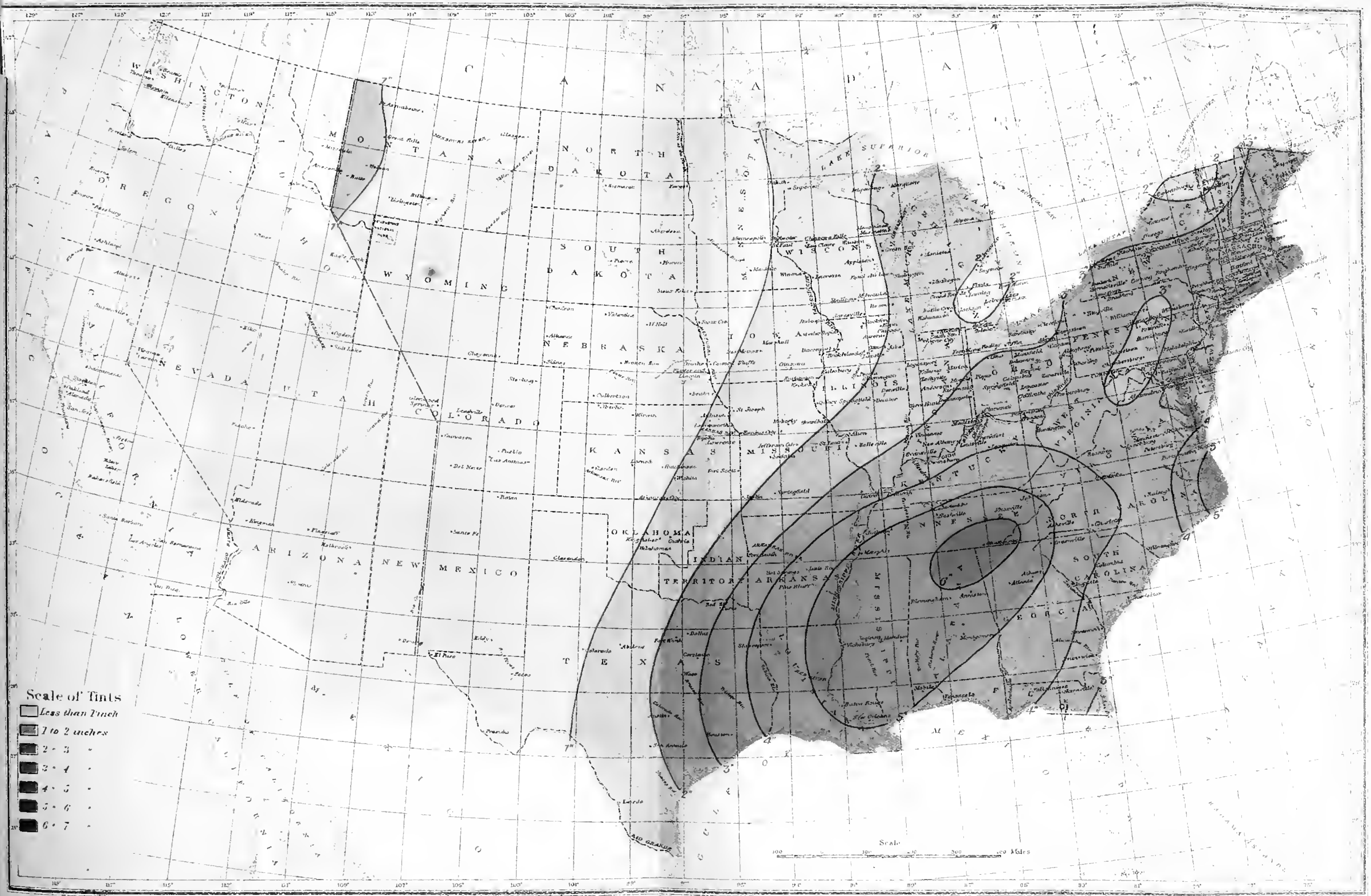


NORMAL HYDROGRAPHS FOR THE YEAR. (Stages referred to the plane of lowest water.)

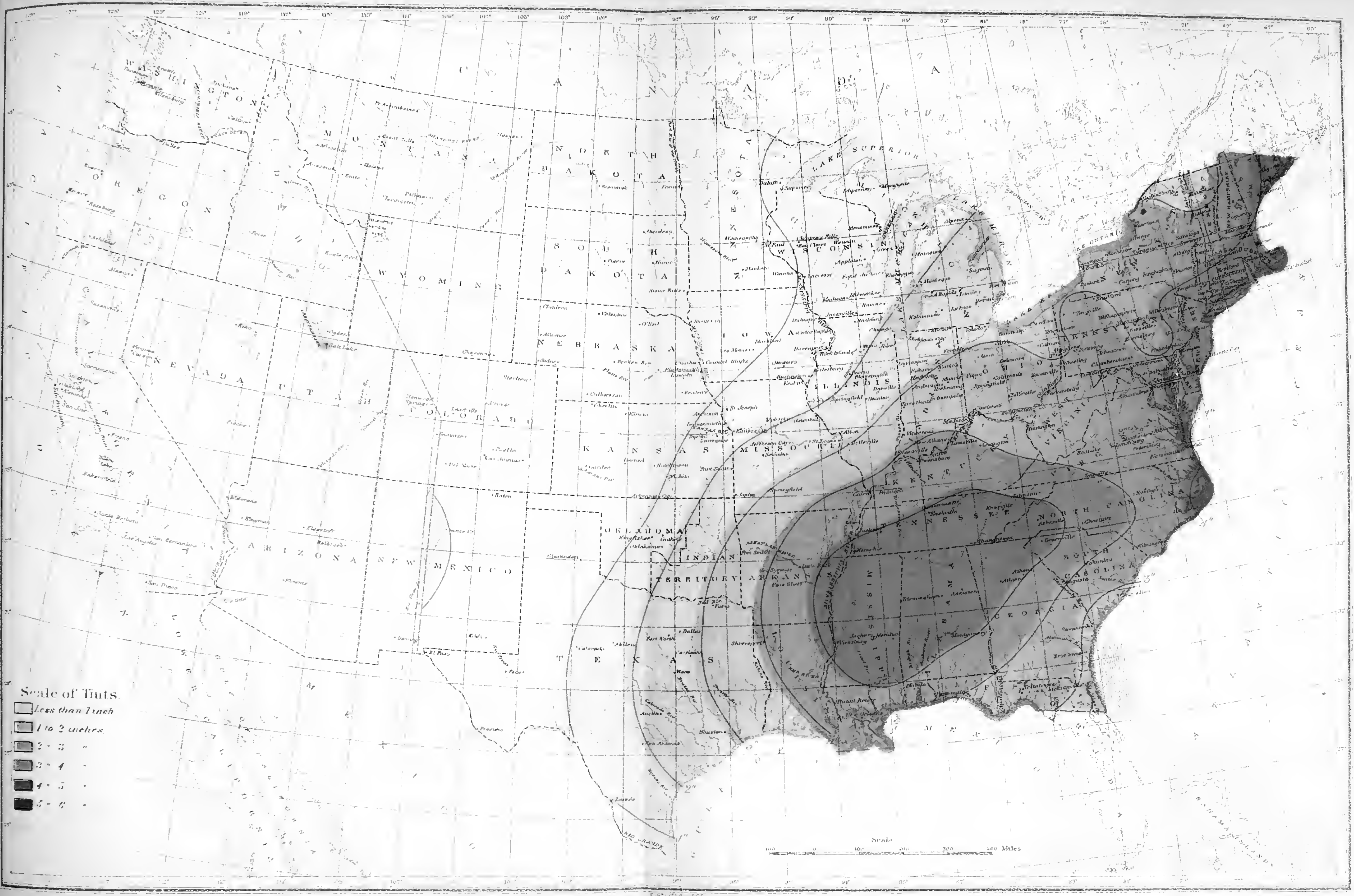


NORMAL ANNUAL PRECIPITATION.

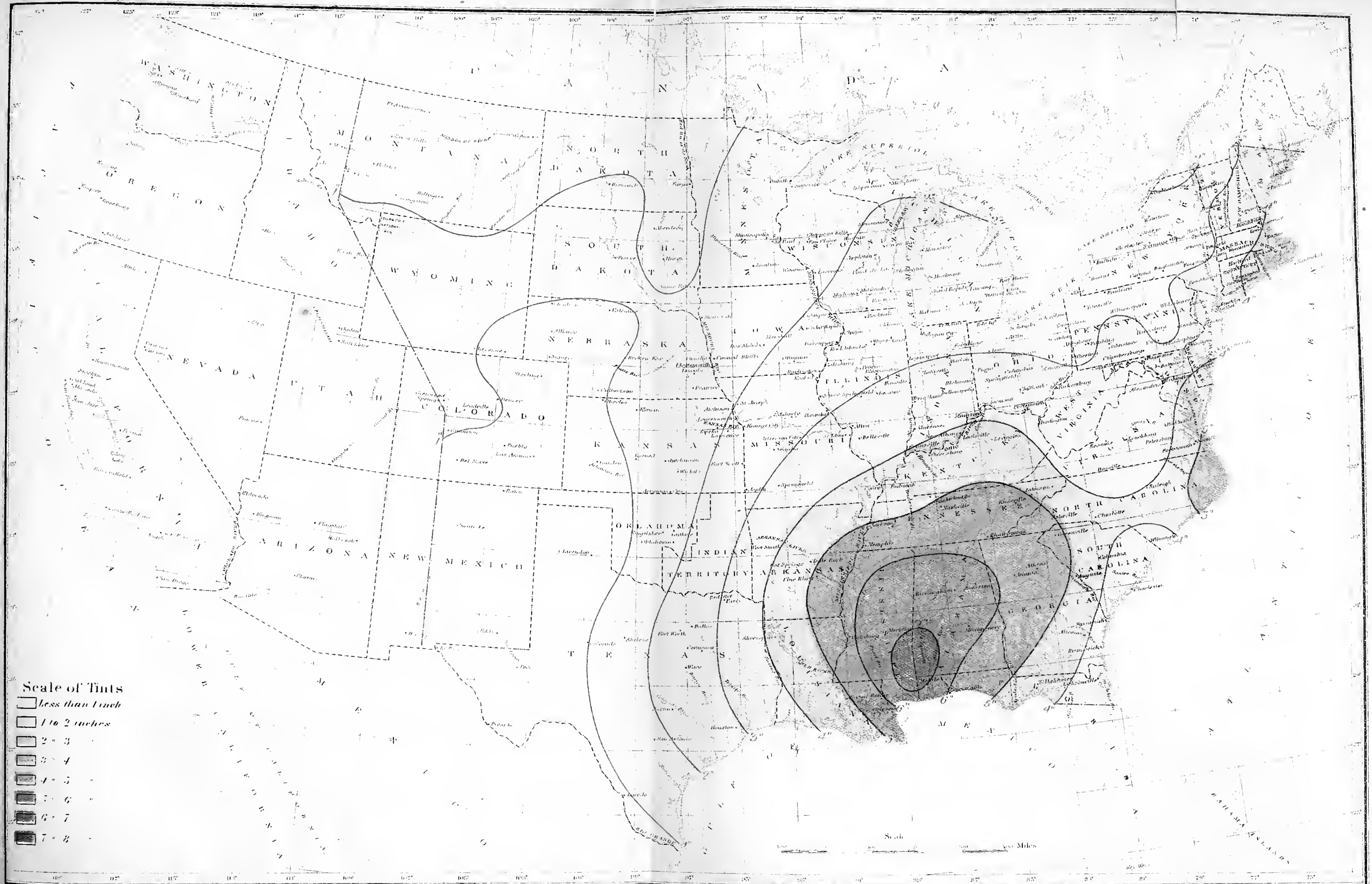


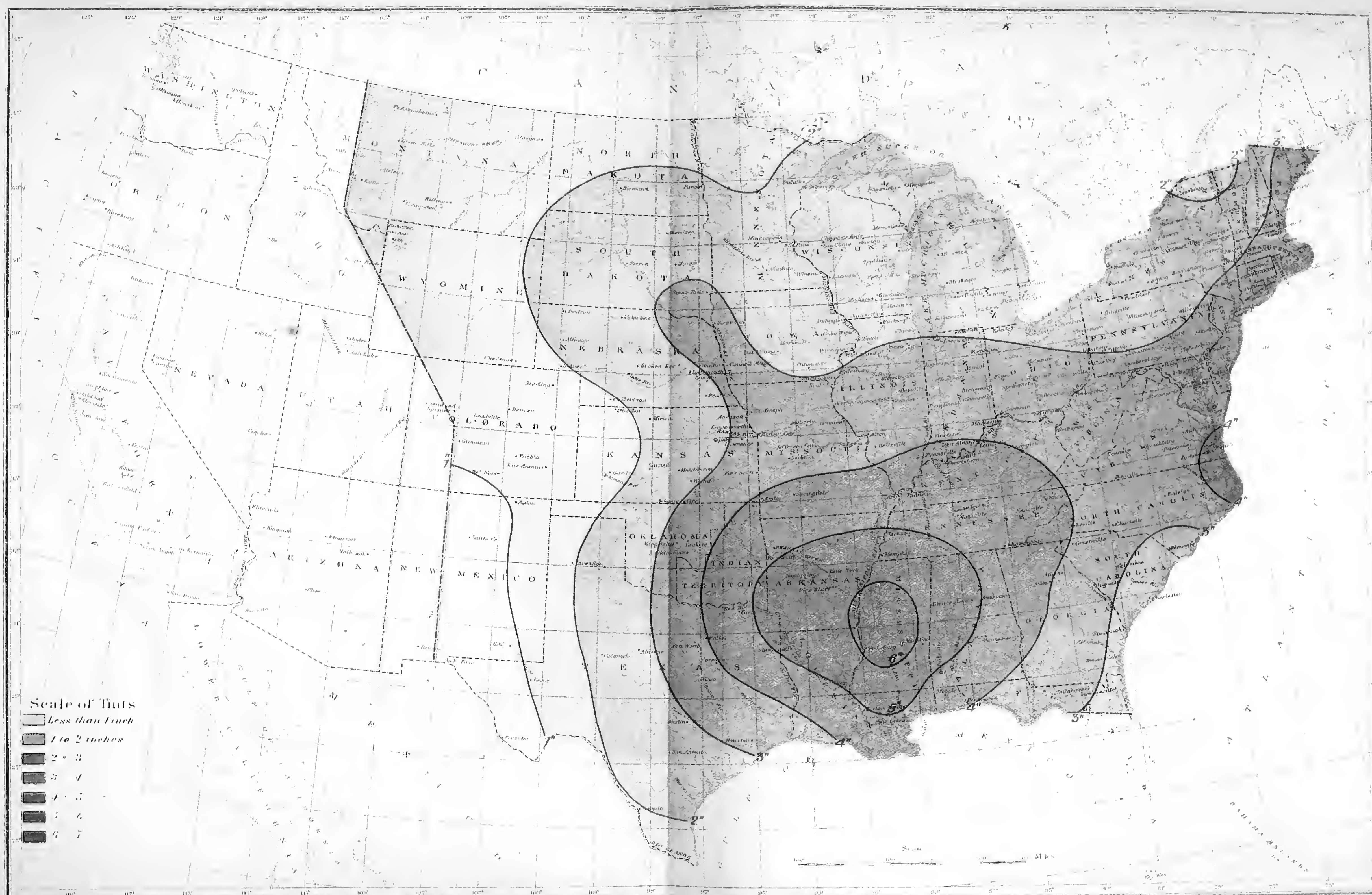

Scale of Tints
Less than 1 inch
1 to 2 inches
2 " 3 "
3 " 4 "
4 " 5 "
5 " 6 "
6 " 7 "
C A N A D A
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
INDIAN TERRITORY
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
WISCONSIN
ILLINOIS
MICHIGAN
KENTUCKY
TENNESSEE
MISSISSIPPI
GEORGIA
SOUTH CAROLINA
NORTH CAROLINA
WEST VIRGINIA
PENNSYLVANIA
LAKE SUPERIOR
LAKE HURON
LAKE ONTARIO
RIO GRANDE
Scale
Miles

NORMAL PRECIPITATION FOR FEBRUARY.

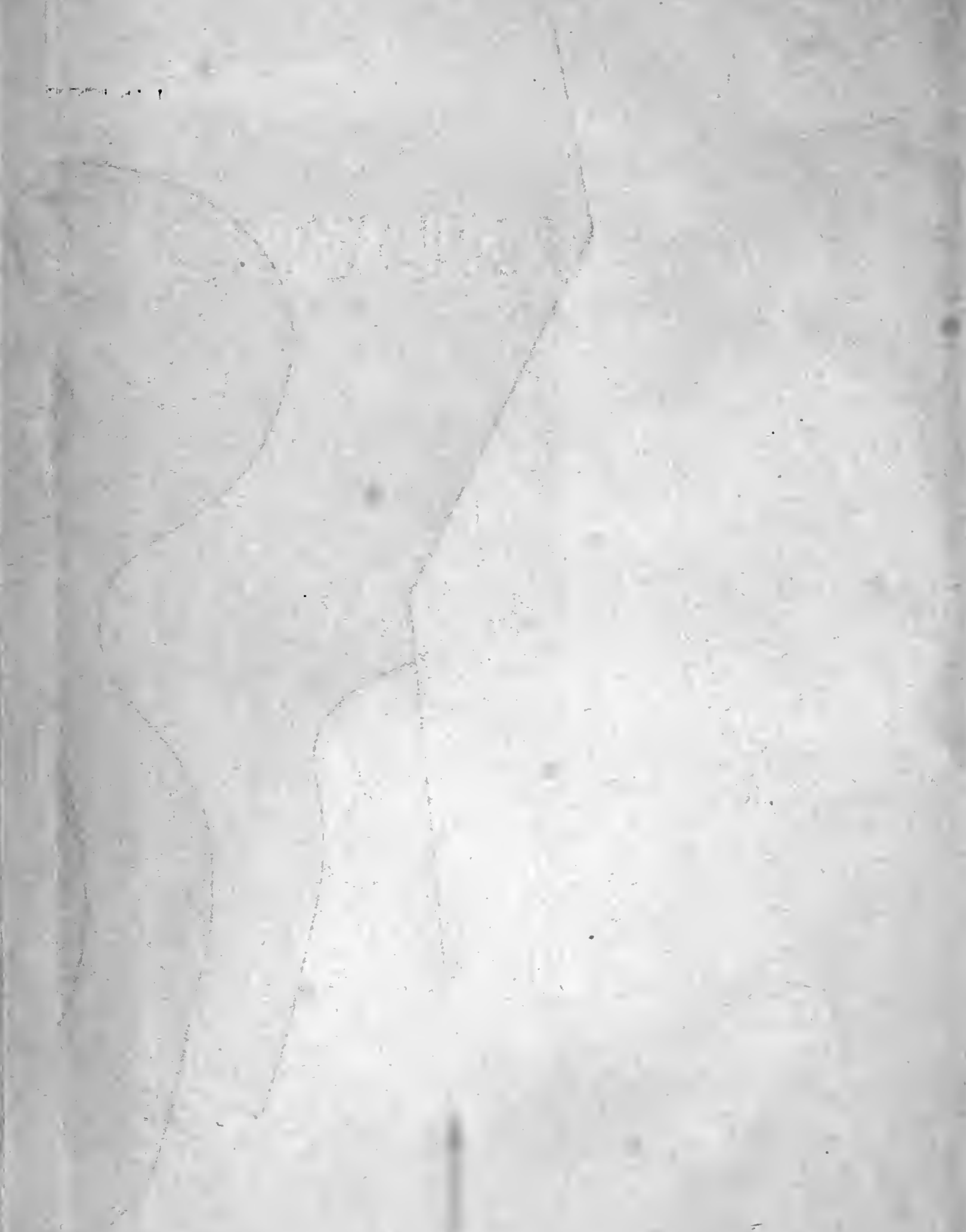


NORMAL PRECIPITATION FOR MARCH.

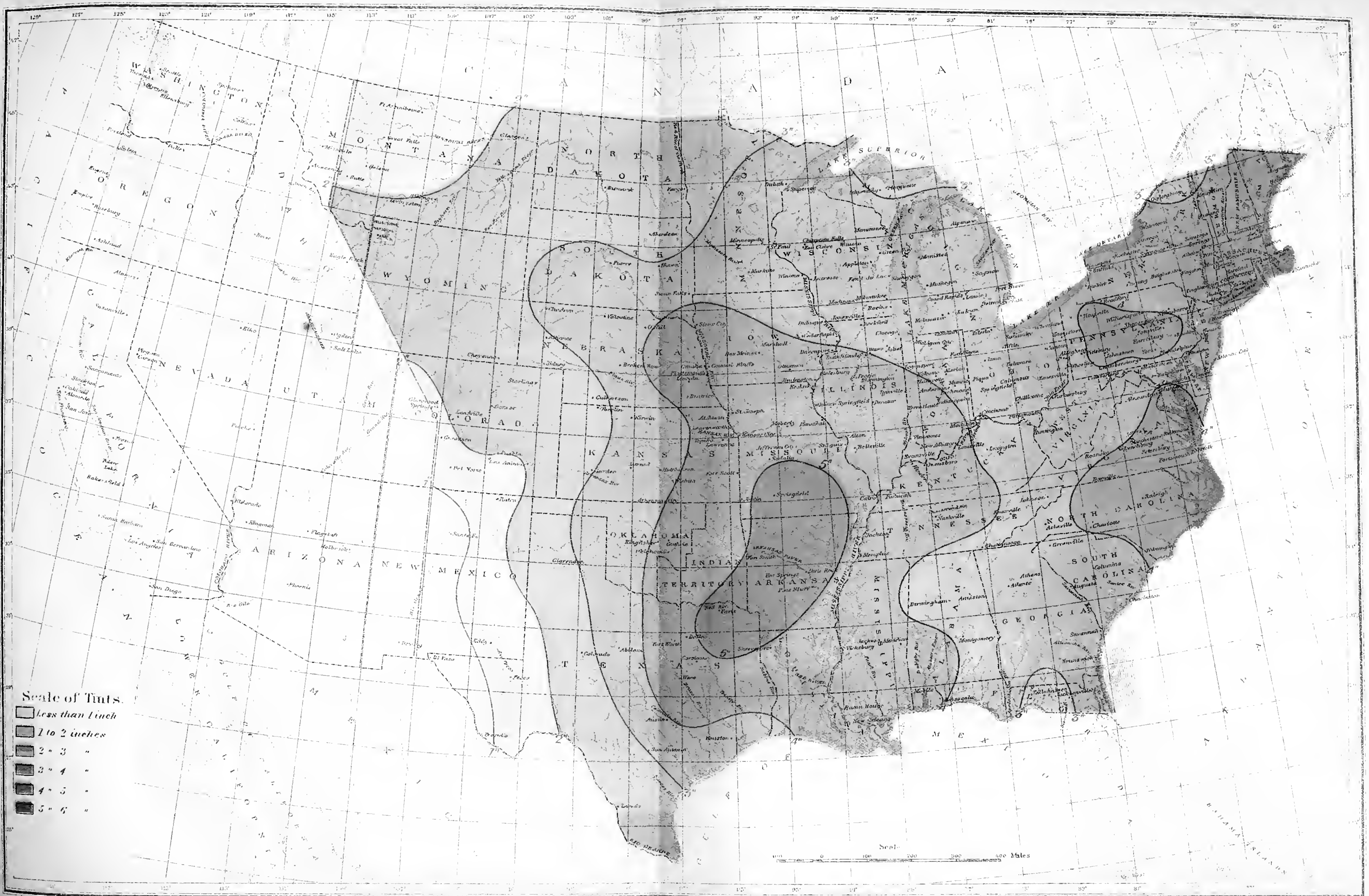




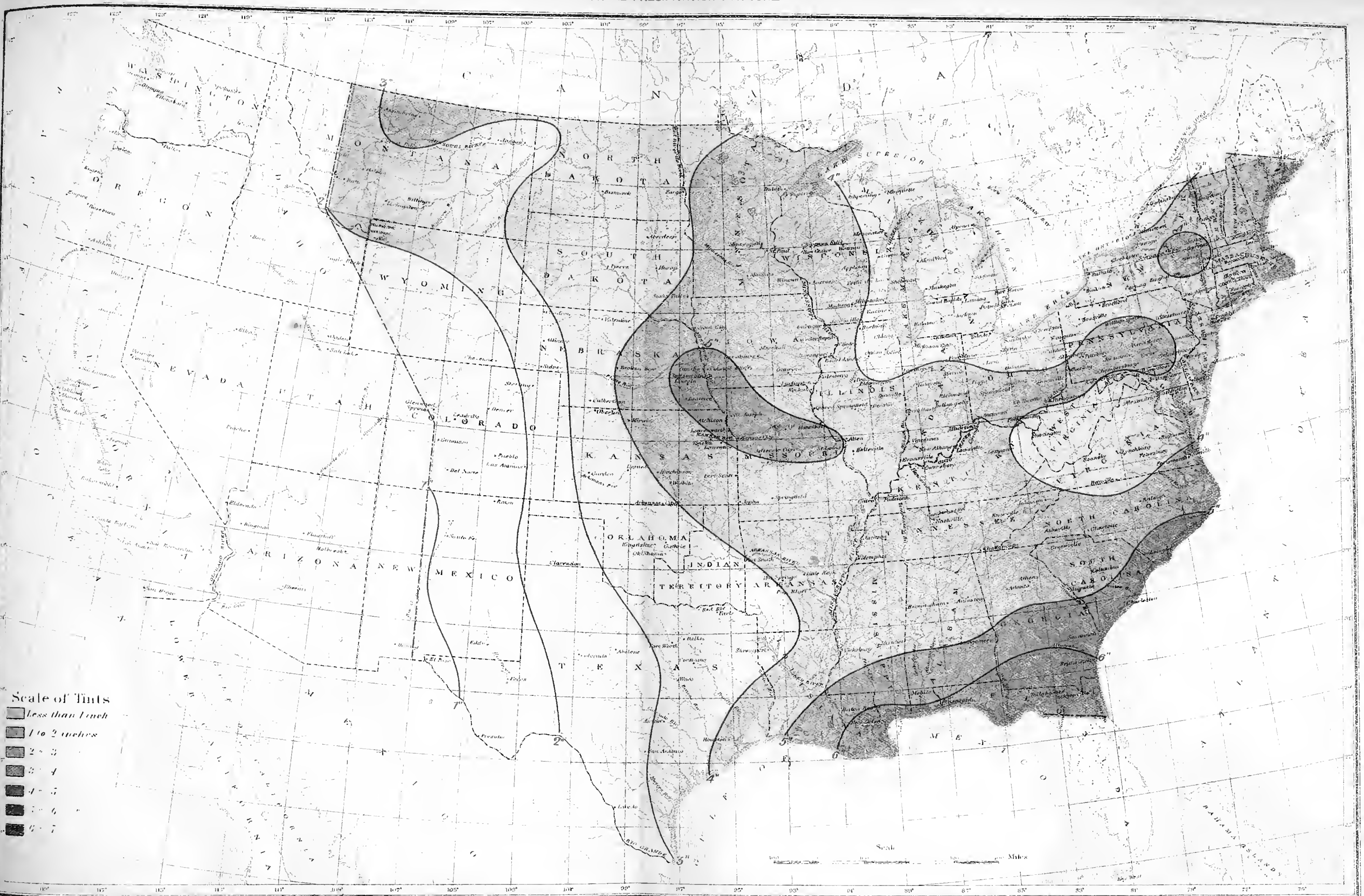
Scale of Tints
Less than 1 inch
1 to 2 inches
2 " 3
3 " 4
4 " 5
5 " 6
6 " 7
WASHINGTON
OREGON
NEVADA
UTAH
ARIZONA
NEW MEXICO
COLORADO
WYOMING
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
INDIAN TERRITORY
ARKANSAS
MISSOURI
ILLINOIS
IOWA
WISCONSIN
OHIO
PENNSYLVANIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
TEXAS
LAKE SUPERIOR



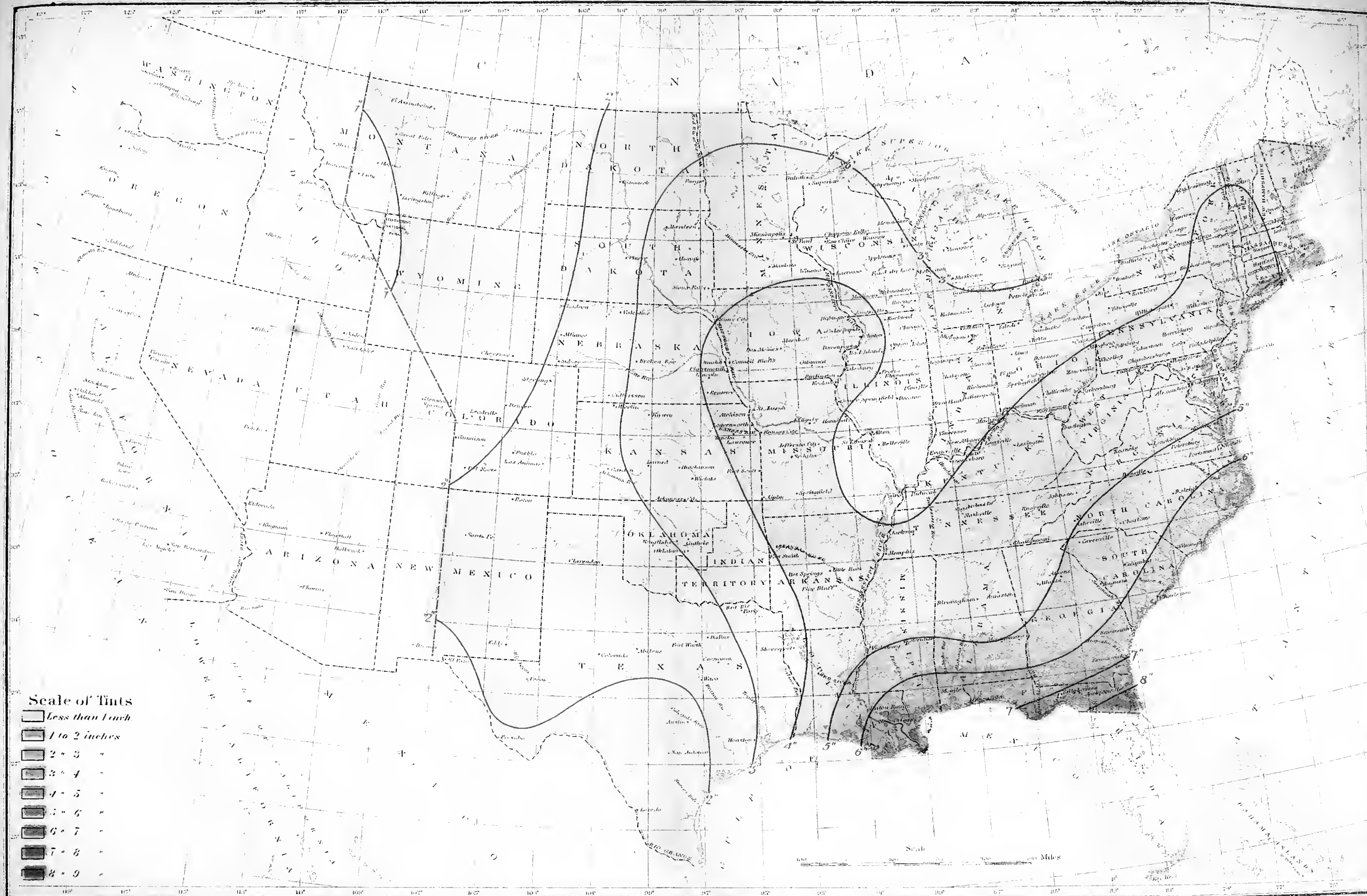
NORMAL PRECIPITATION FOR MAY.



NORMAL PRECIPITATION FOR JUNE.

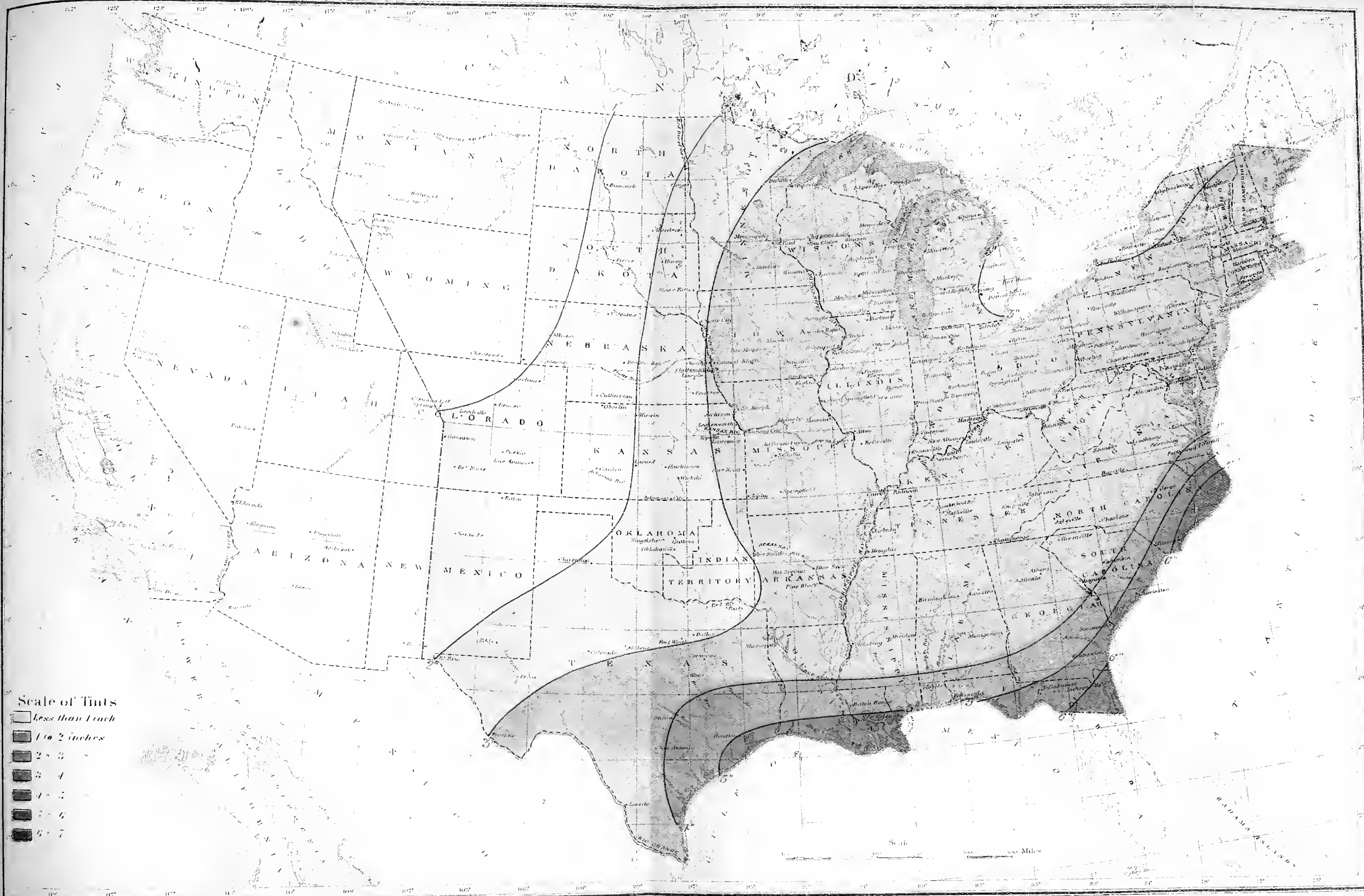


NORMAL PRECIPITATION FOR JULY.

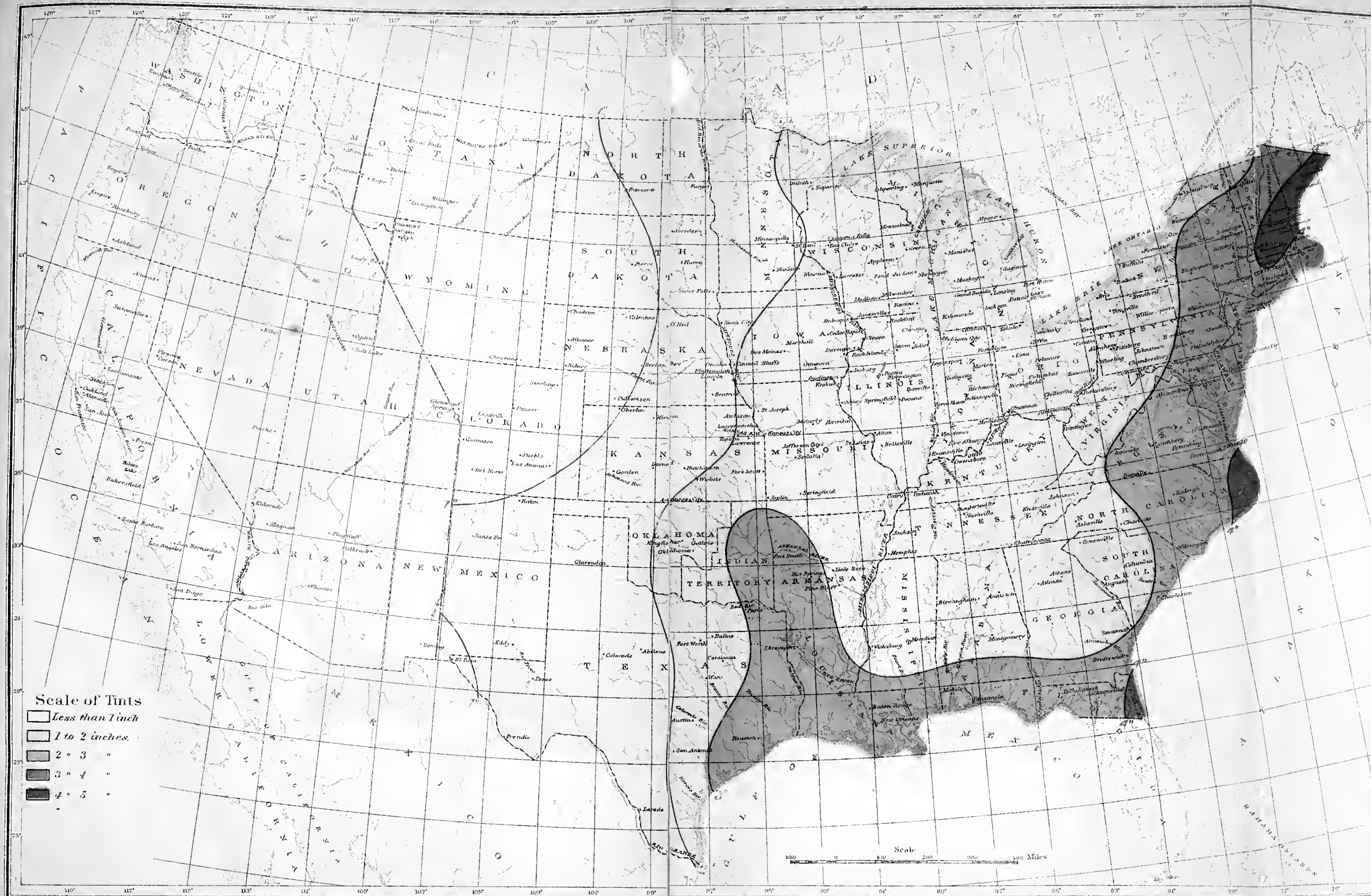


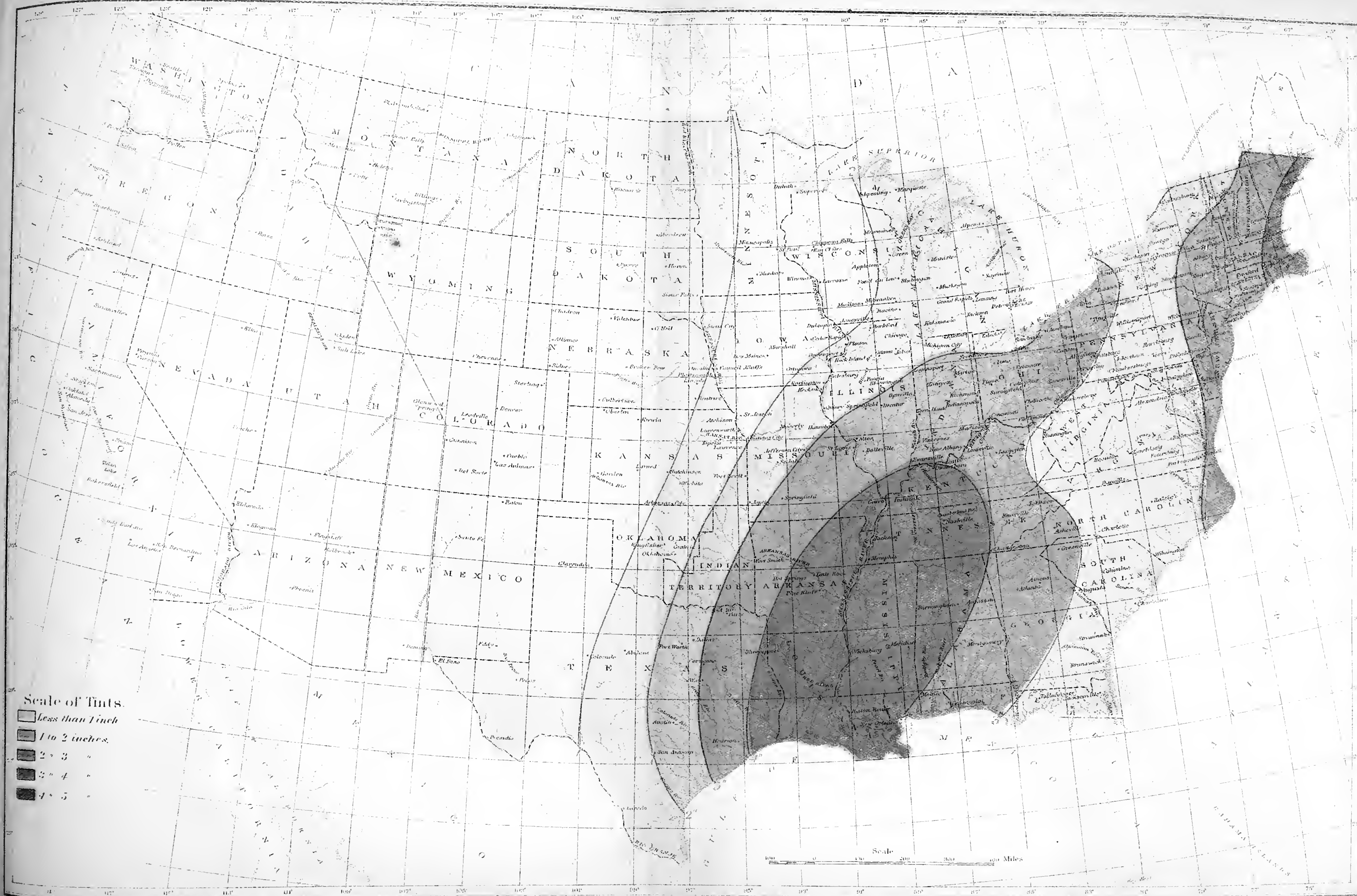
NORMAL PRECIPITATION FOR AUGUST.

NORMAL PRECIPITATION FOR SEPTEMBER.

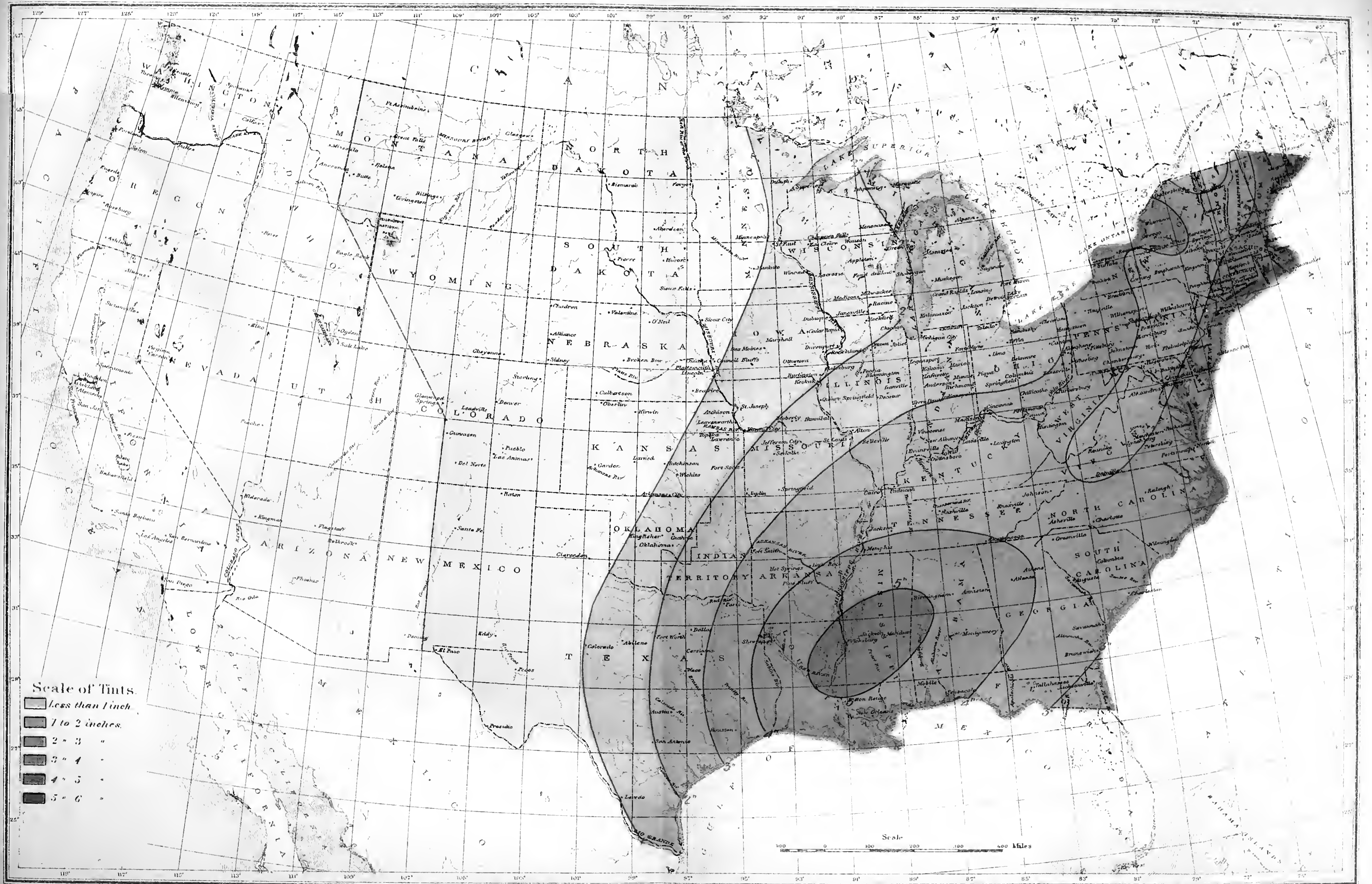


NORMAL PRECIPITATION FOR OCTOBER.

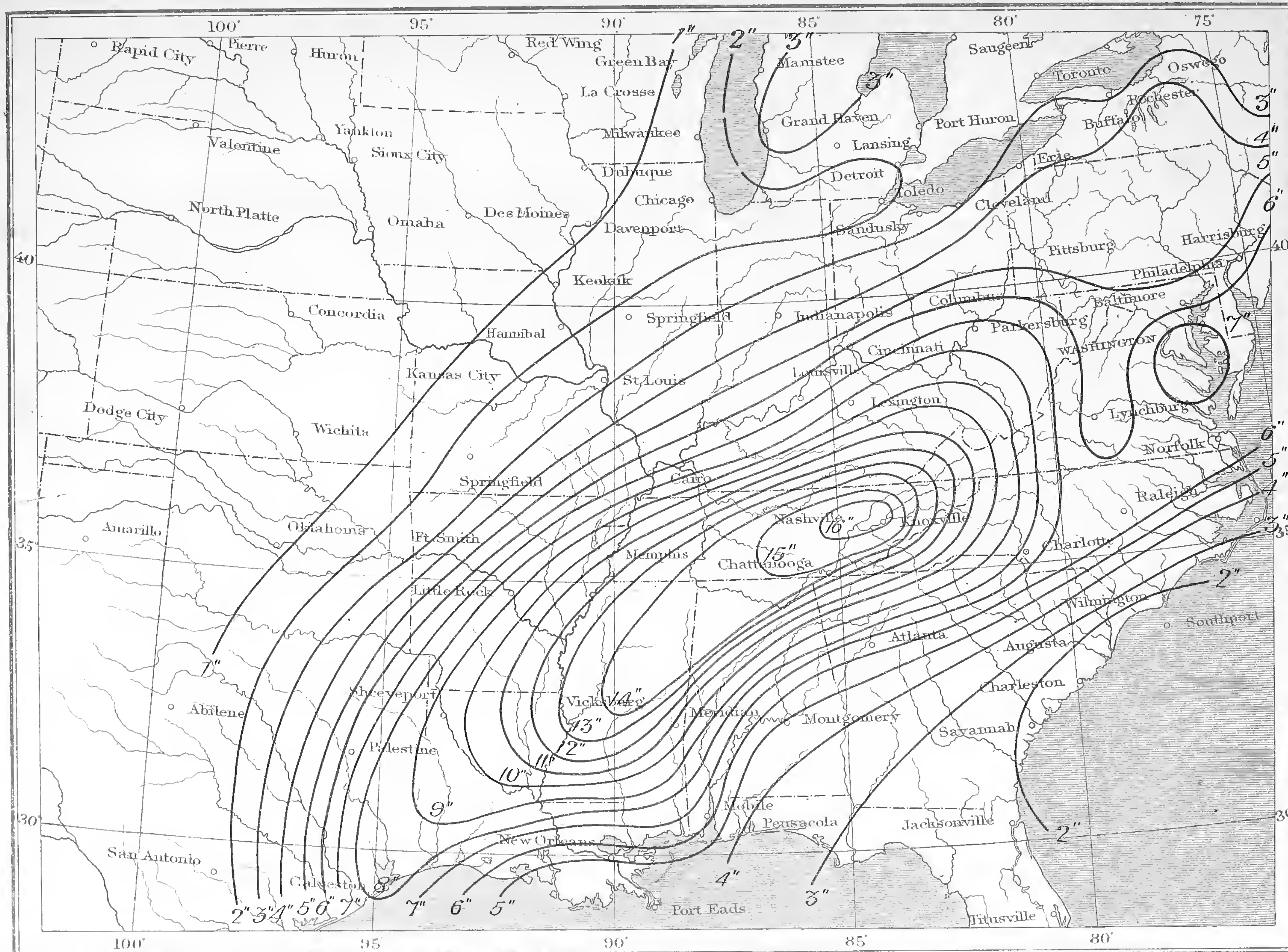



Scale of Tints.
Less than 1 inch
1 to 2 inches.
2 " 3 "
3 " 4 "
4 " 5 "
Scale
Miles

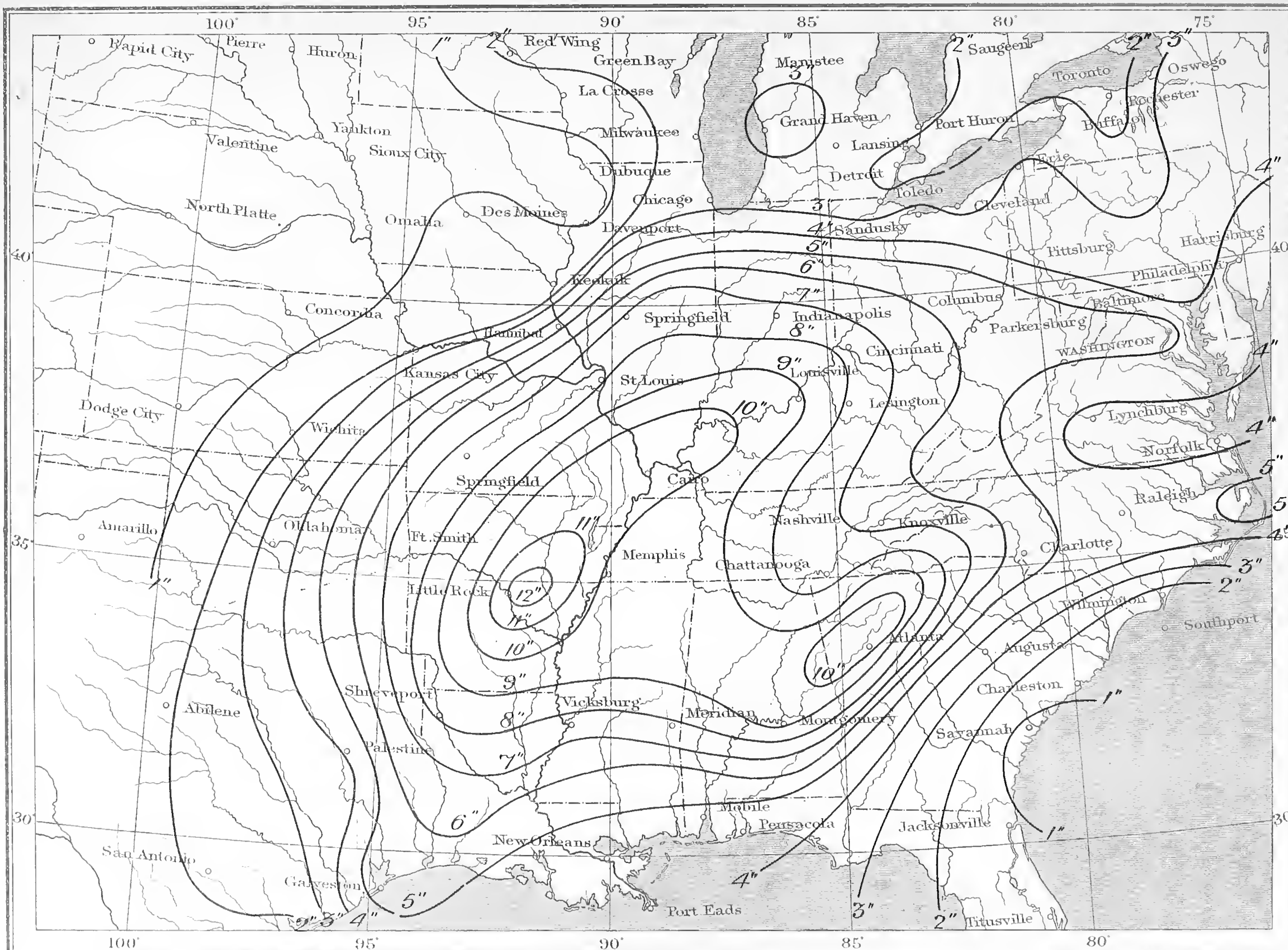
NORMAL PRECIPITATION FOR DECEMBER.



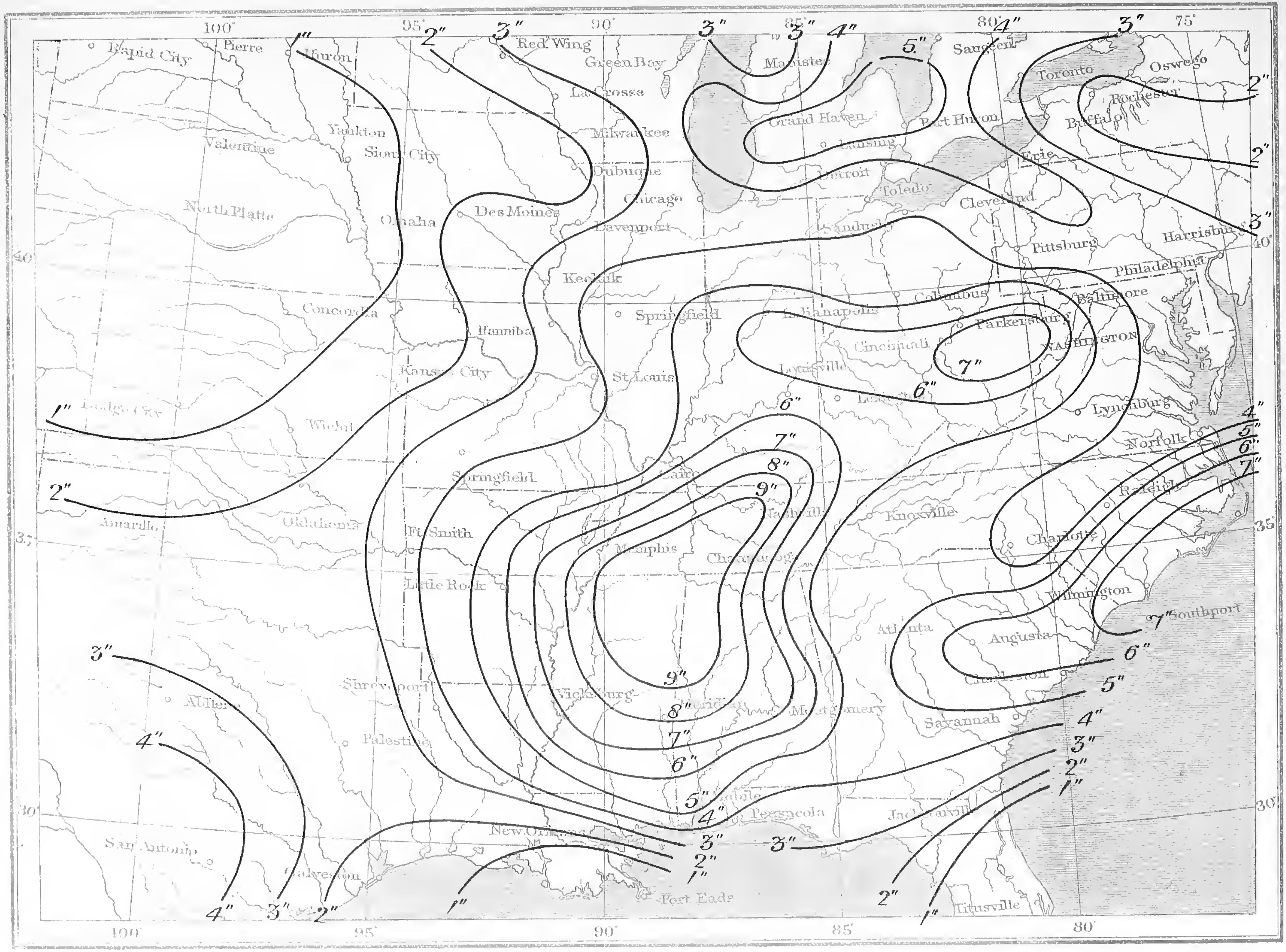
PRECIPITATION FOR JANUARY, 1882.



PRECIPITATION FOR FEBRUARY, 1882.

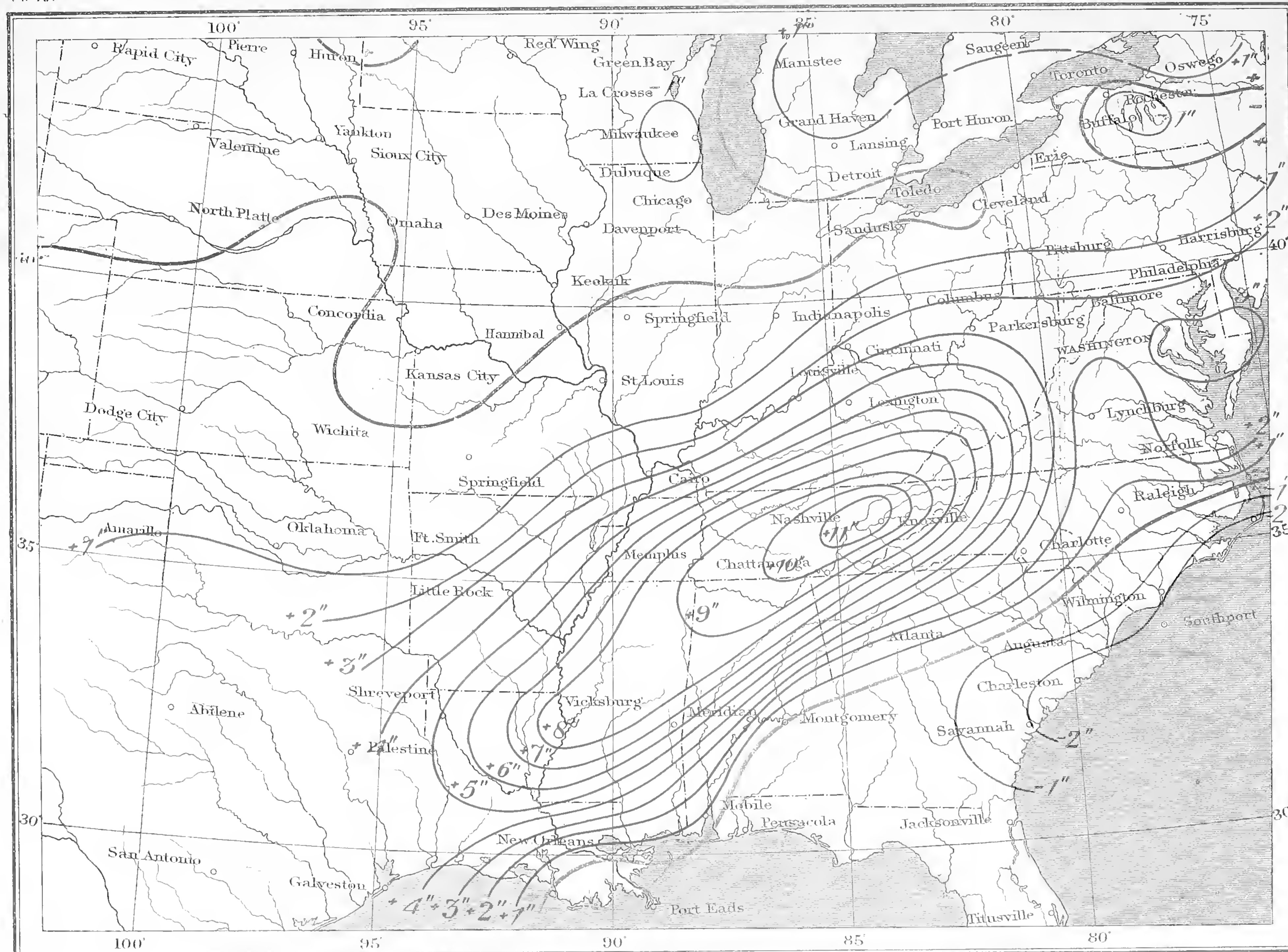


PRECIPITATION FOR MARCH, 1882.

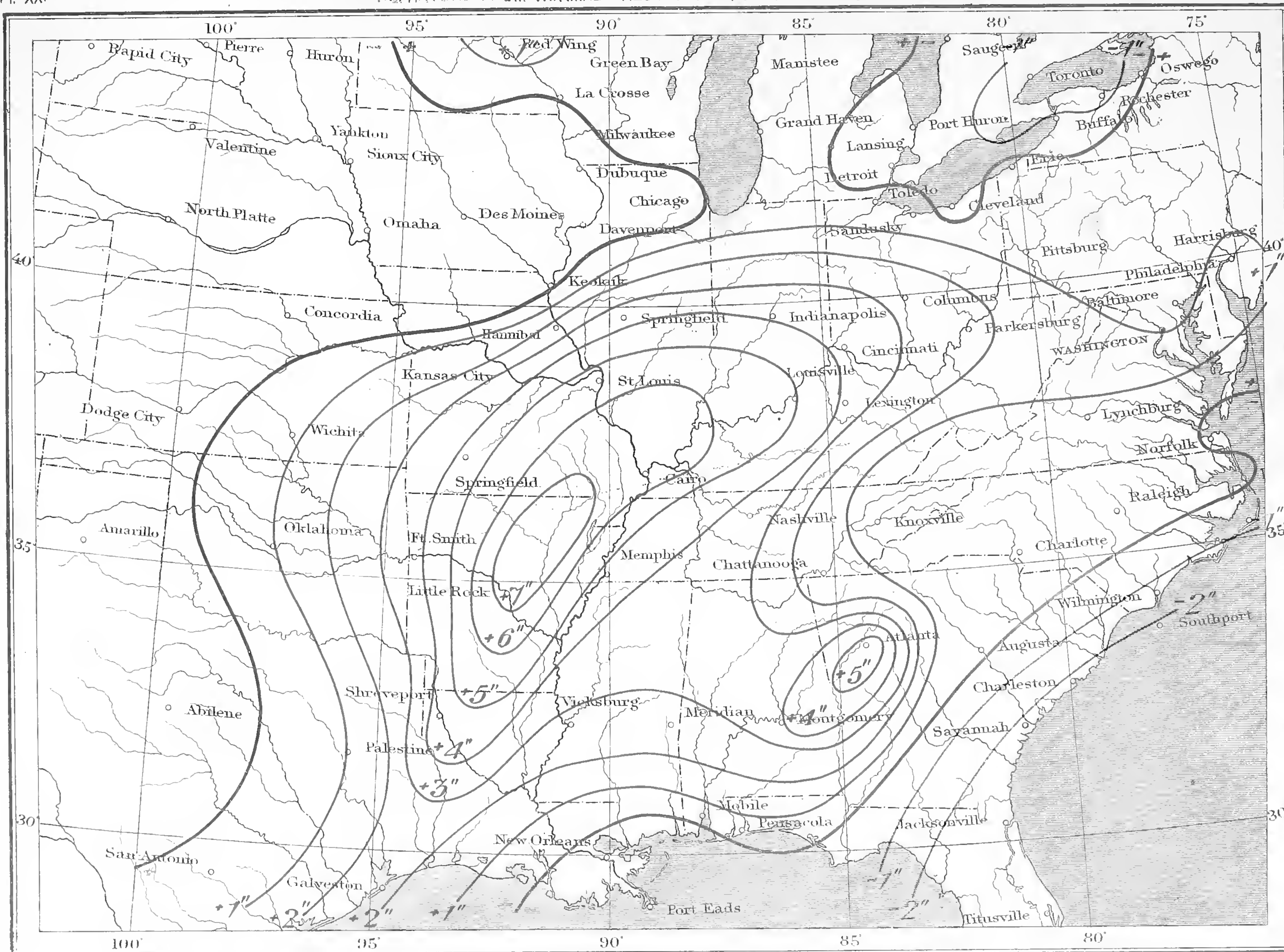


Pl. XX.

DEPARTURE FROM NORMAL PRECIPITATION, JANUARY 1882.

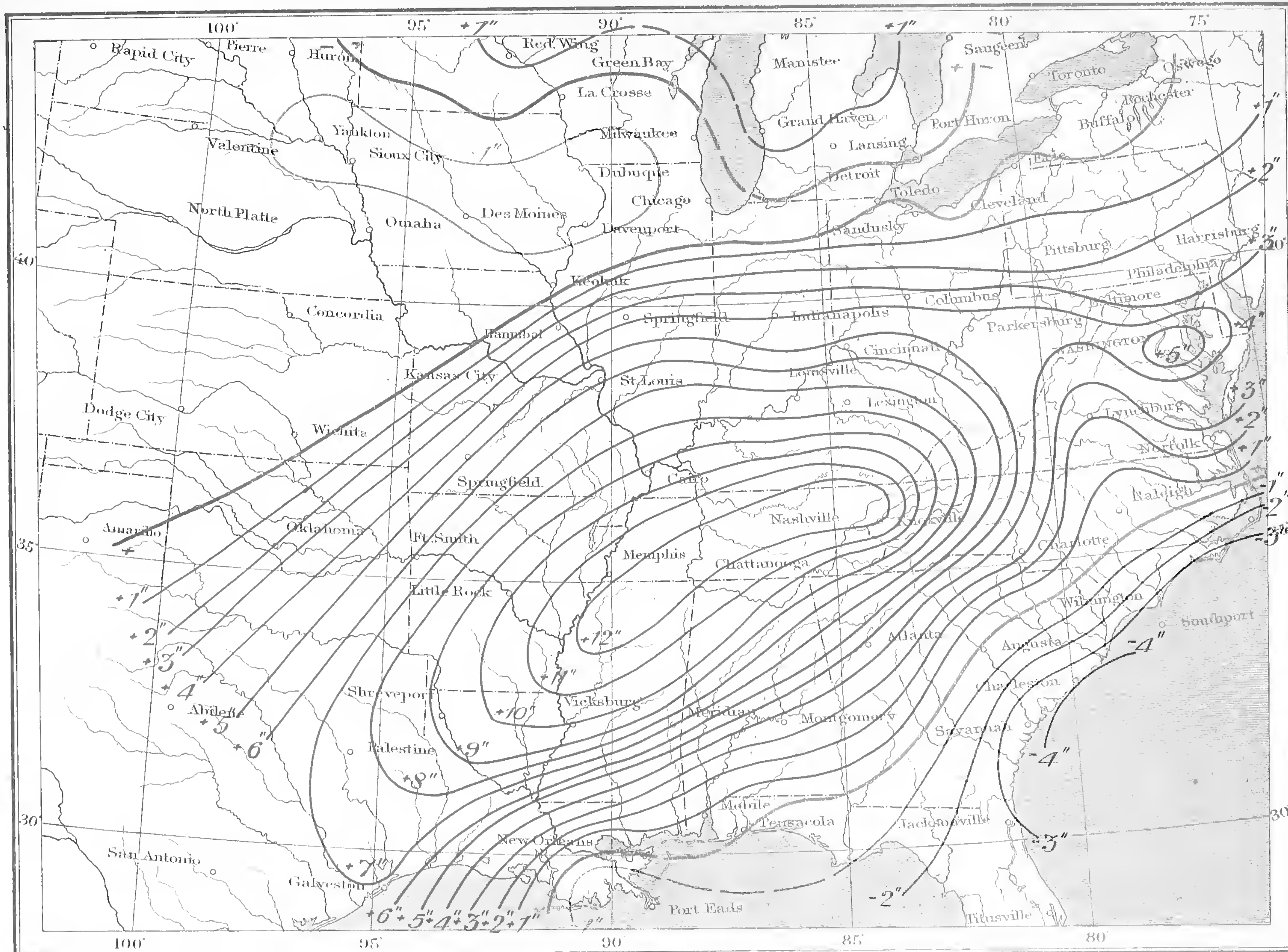


DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY, 1882.

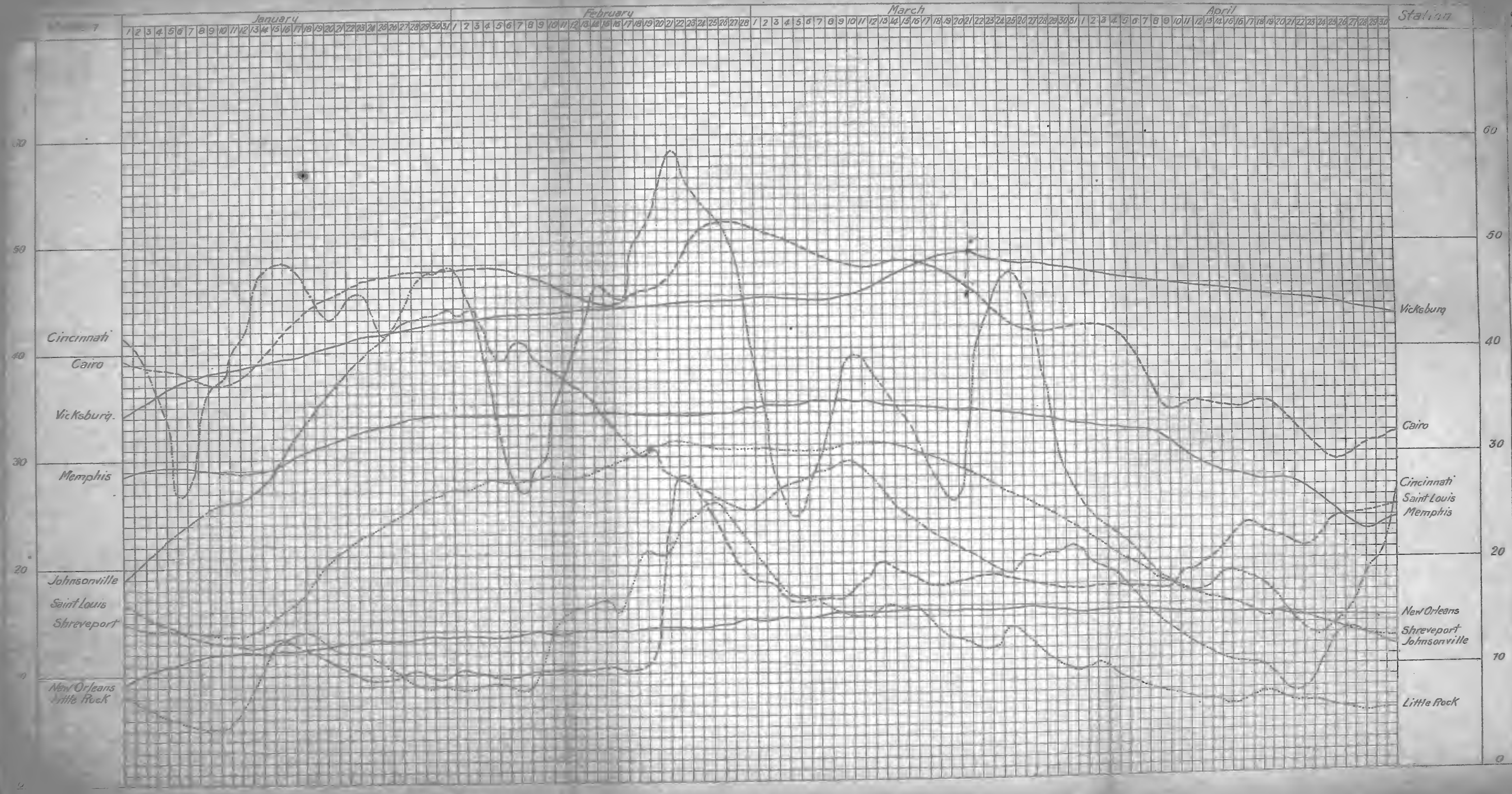


Pl. XXII.

DEPARTURE FROM NORMAL PRECIPITATION, JANUARY 1 TO FEBRUARY 28, 1882.

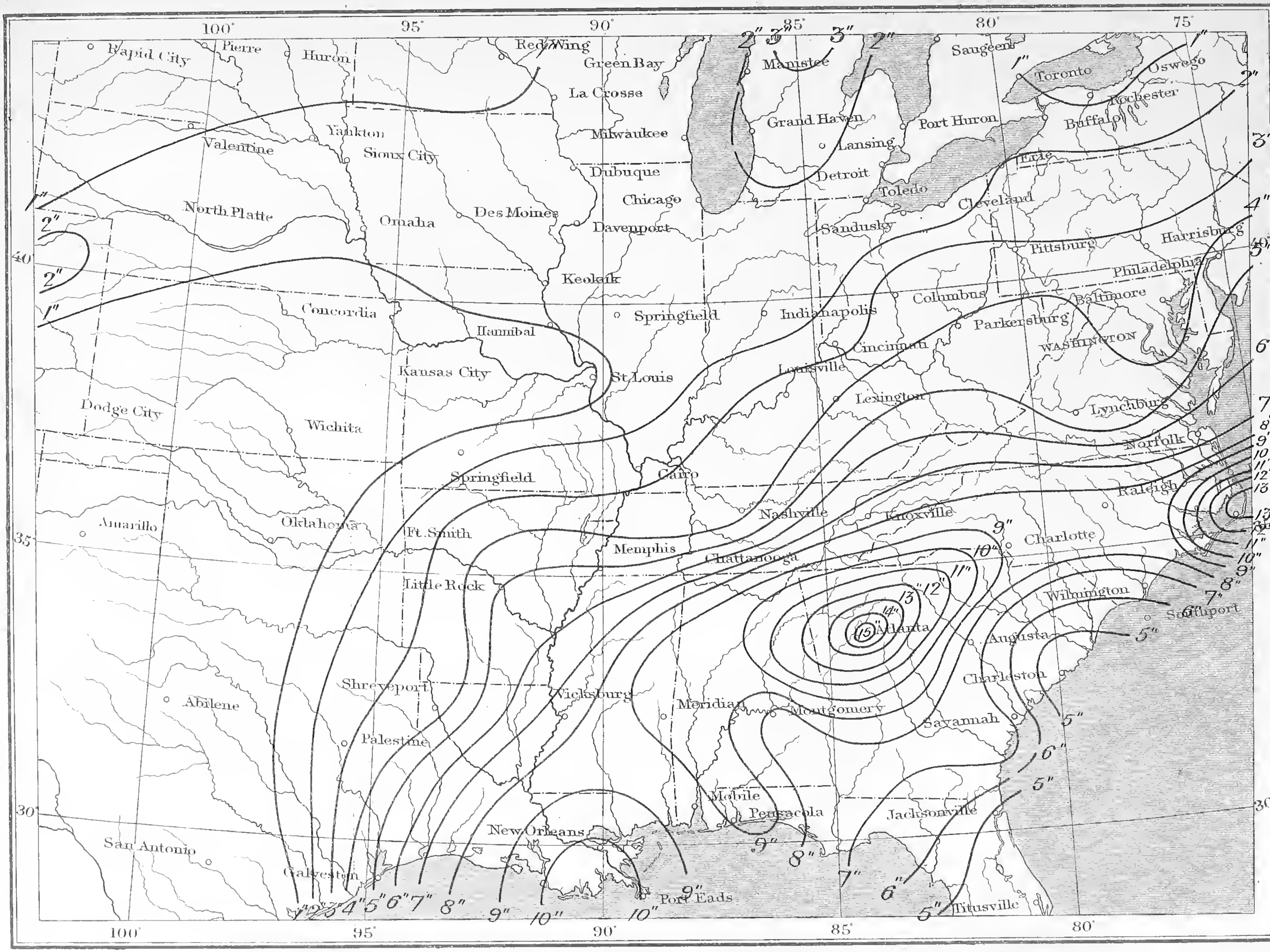


HYDROGRAPHS FOR FLOOD OF 1882.

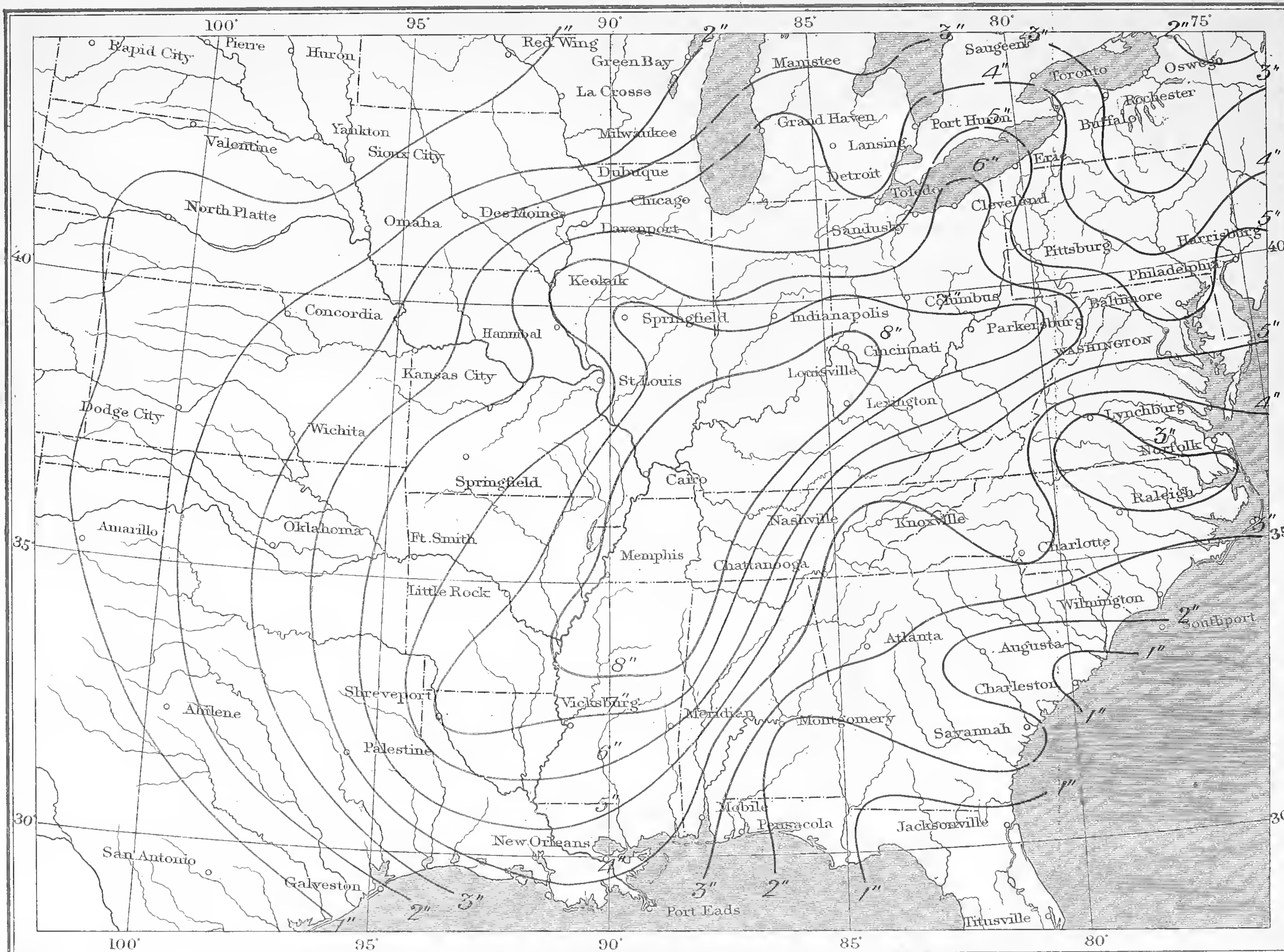


Pl. XXIV.

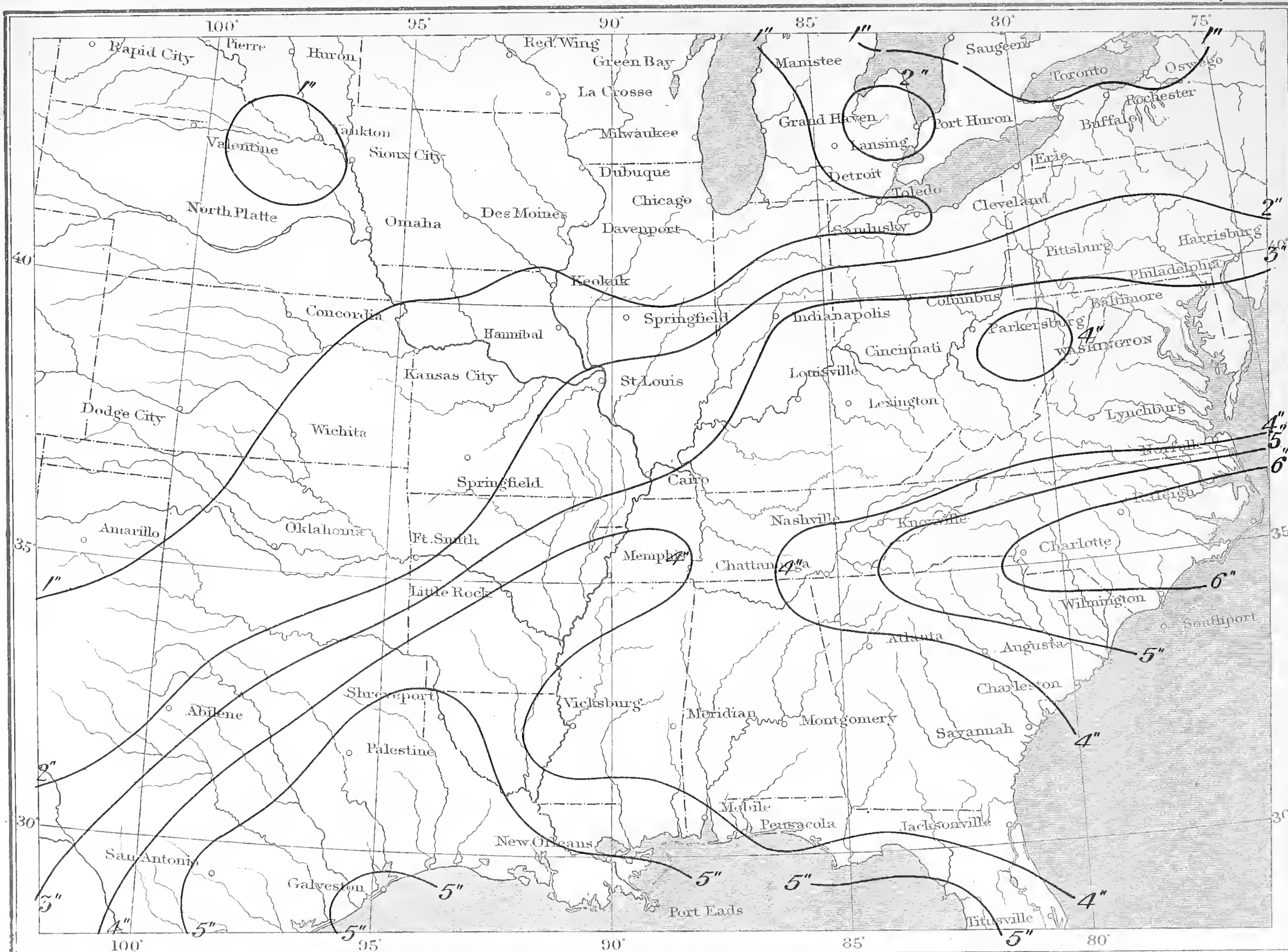
PRECIPITATION FOR JANUARY, 1883.



PRECIPITATION FOR FEBRUARY, 1883.

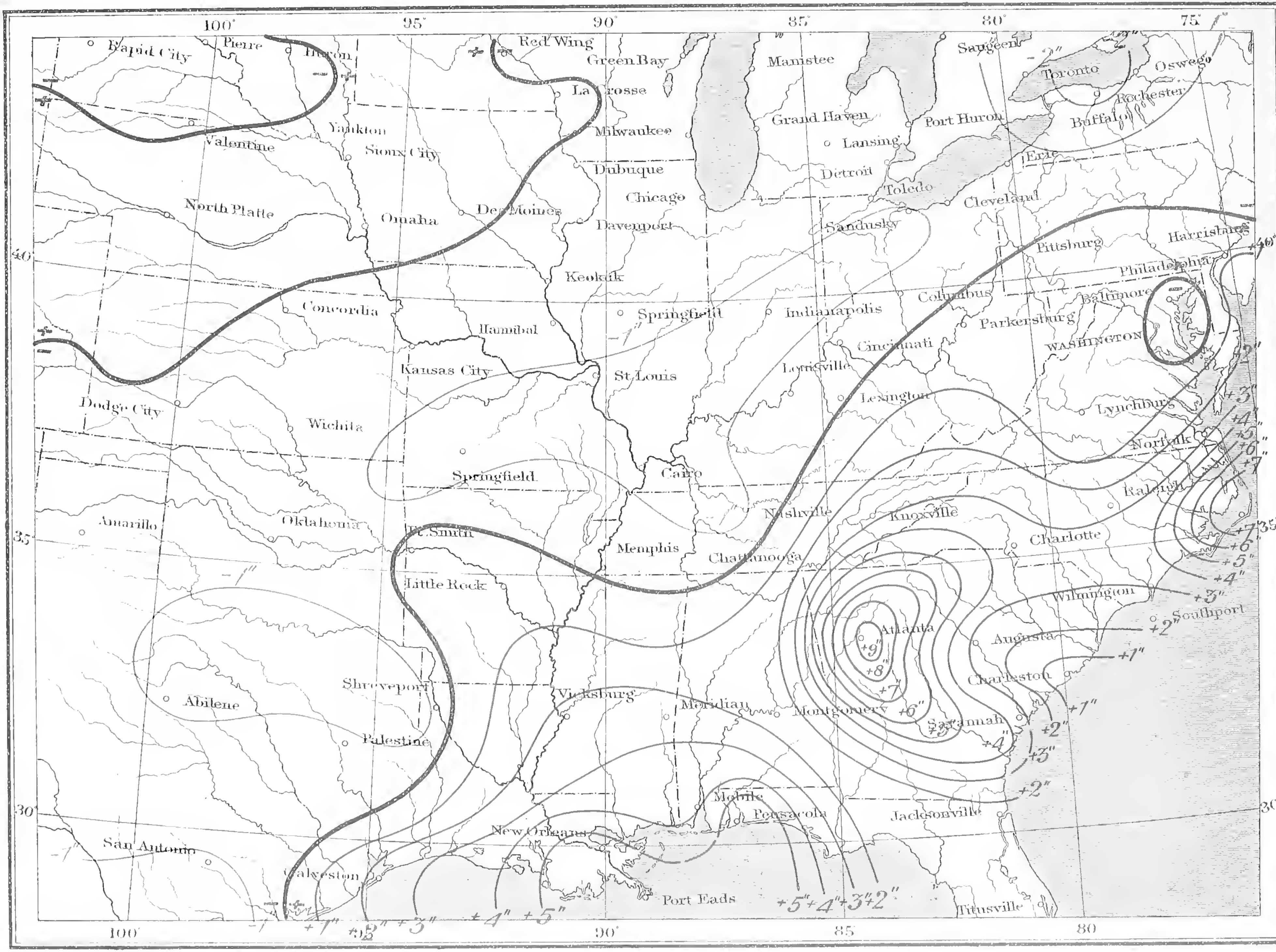


Pl. XXVI. PRECIPITATION FOR MARCH, 1883.



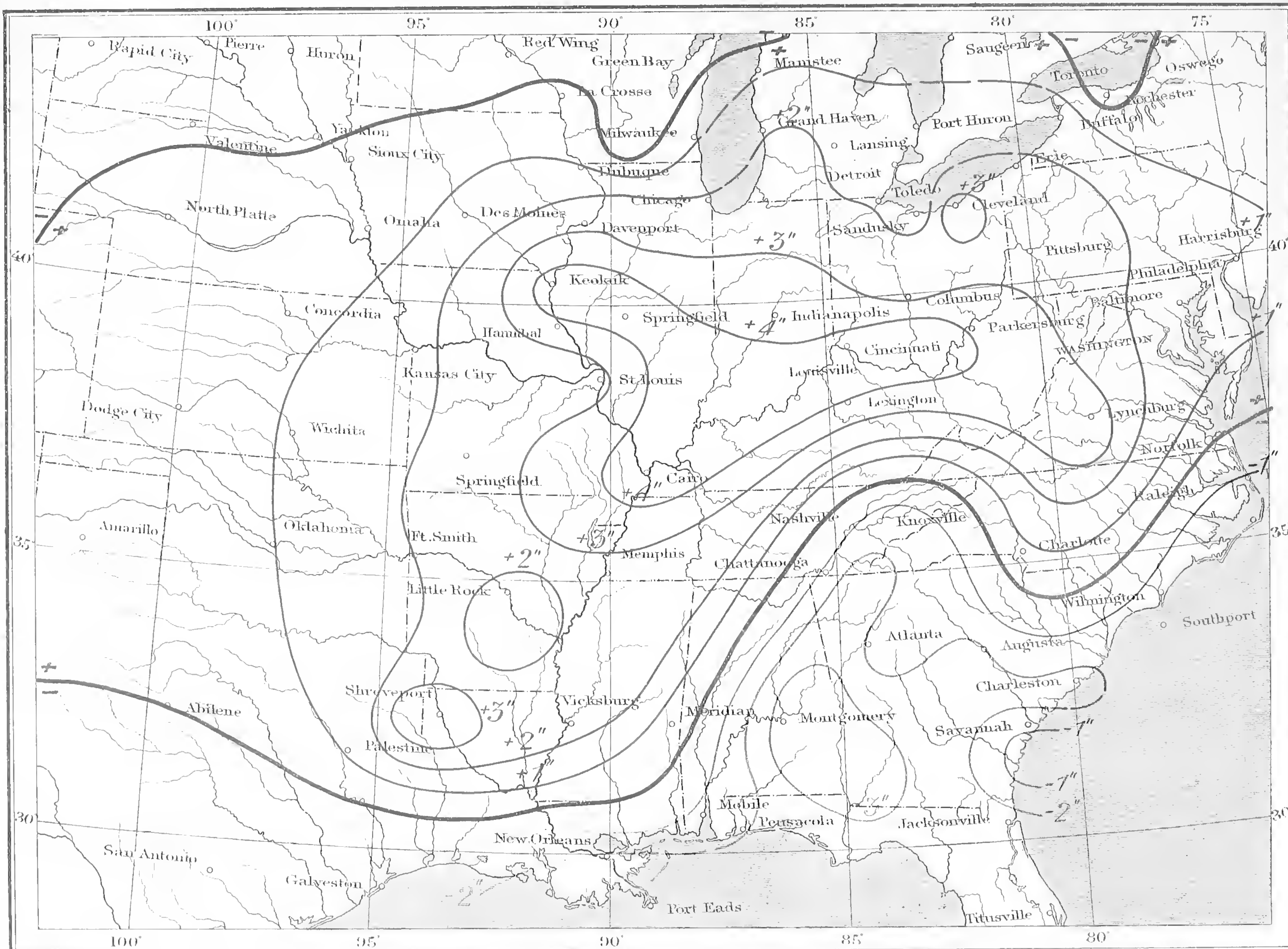
Pl. XXVII.

DEPARTURE FROM NORMAL PRECIPITATION, JANUARY, 1883.



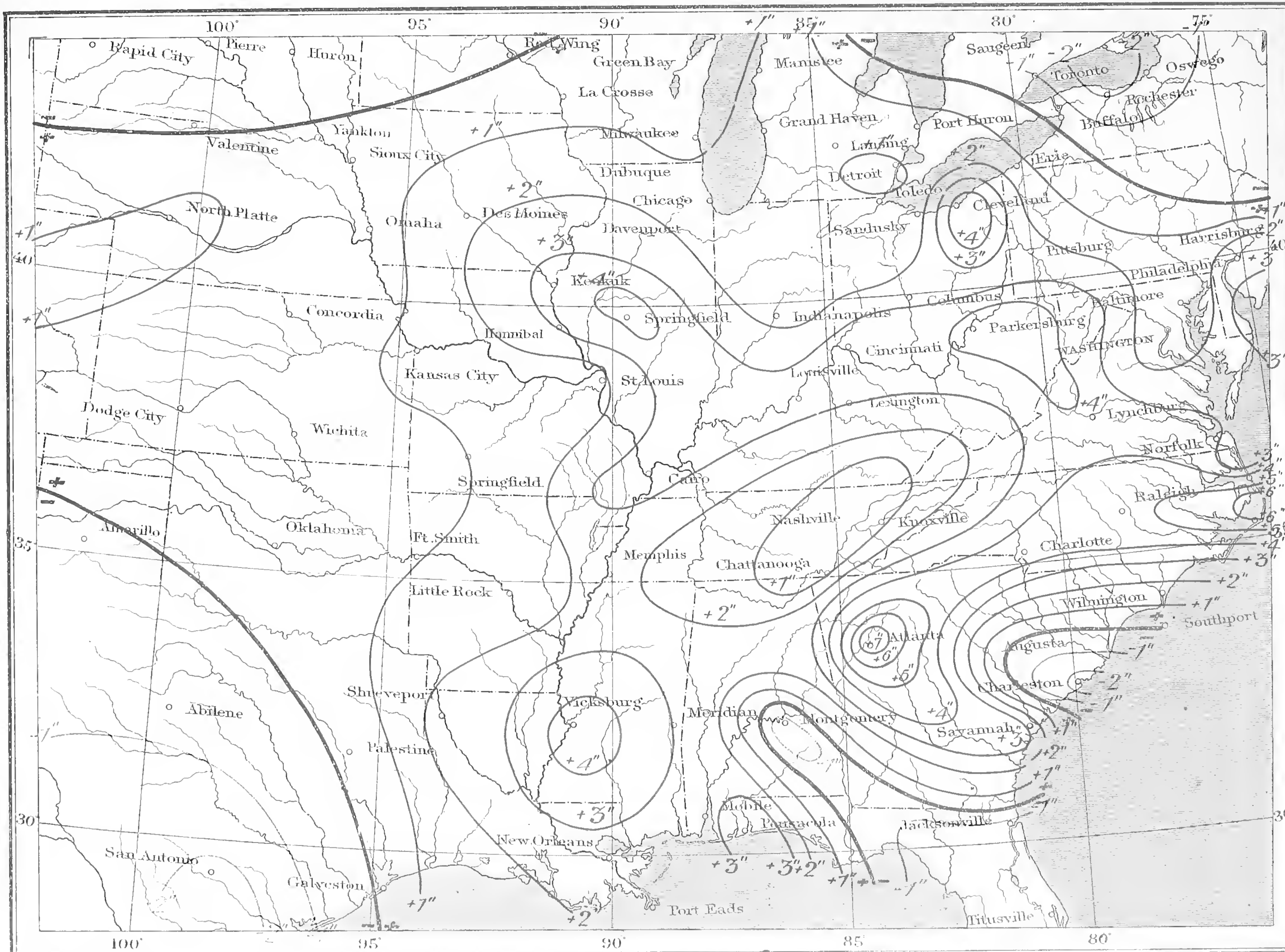
Pl. XXVIII.

DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY, 1883.

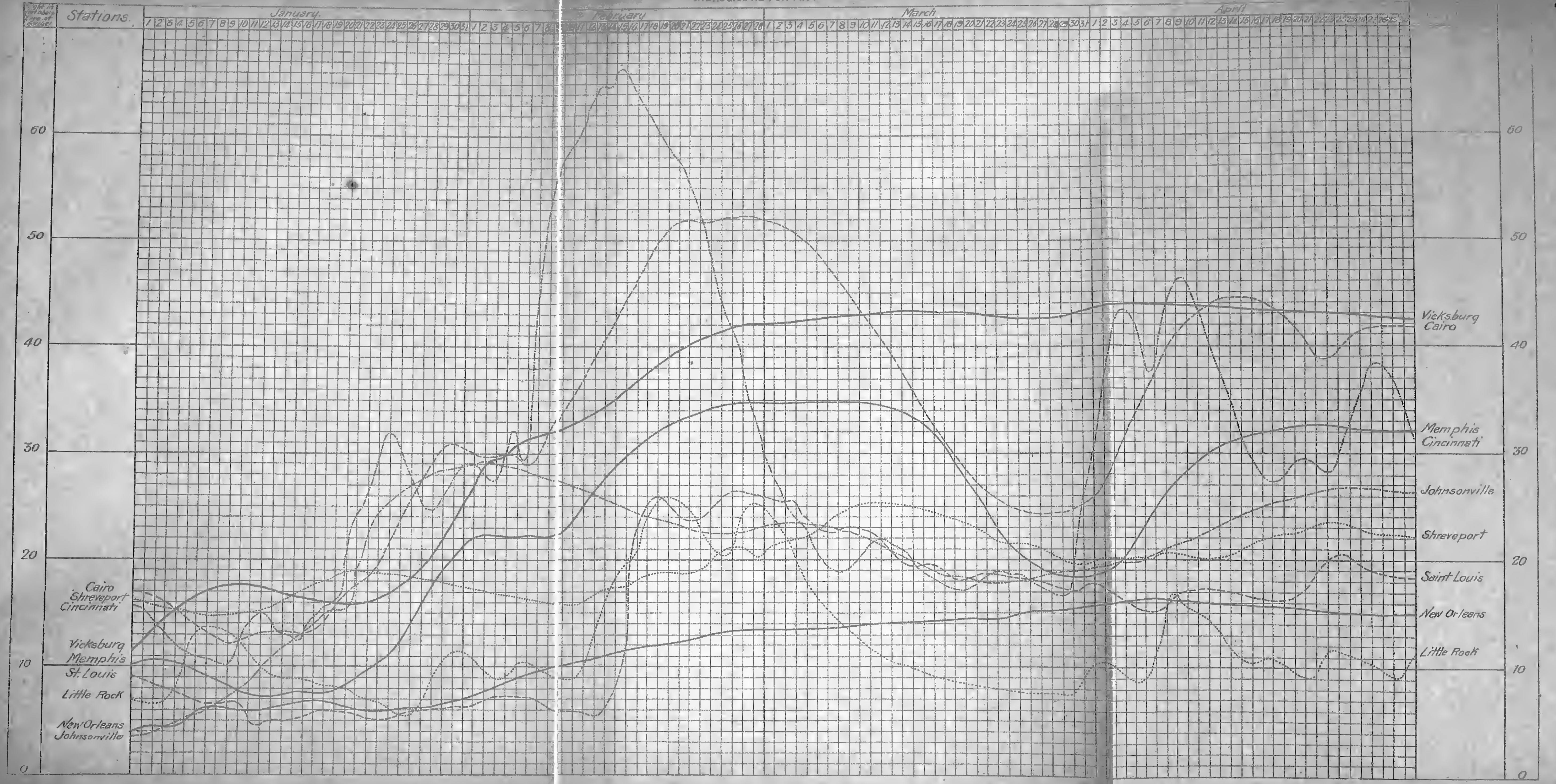


Pl. XXIX.

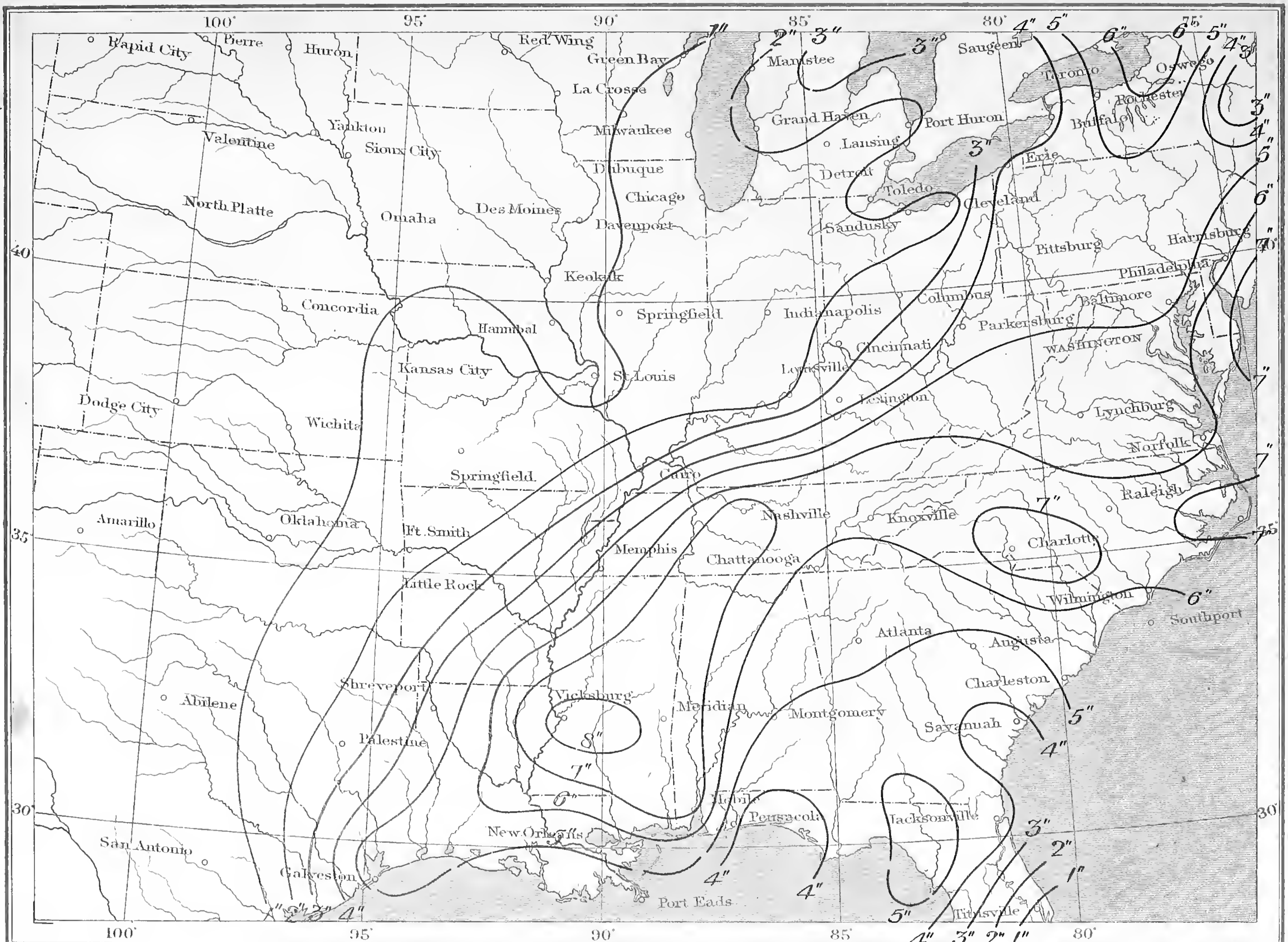
DEPARTURE FROM NORMAL PRECIPITATION, JANUARY 1 TO FEBRUARY 28, 1883.



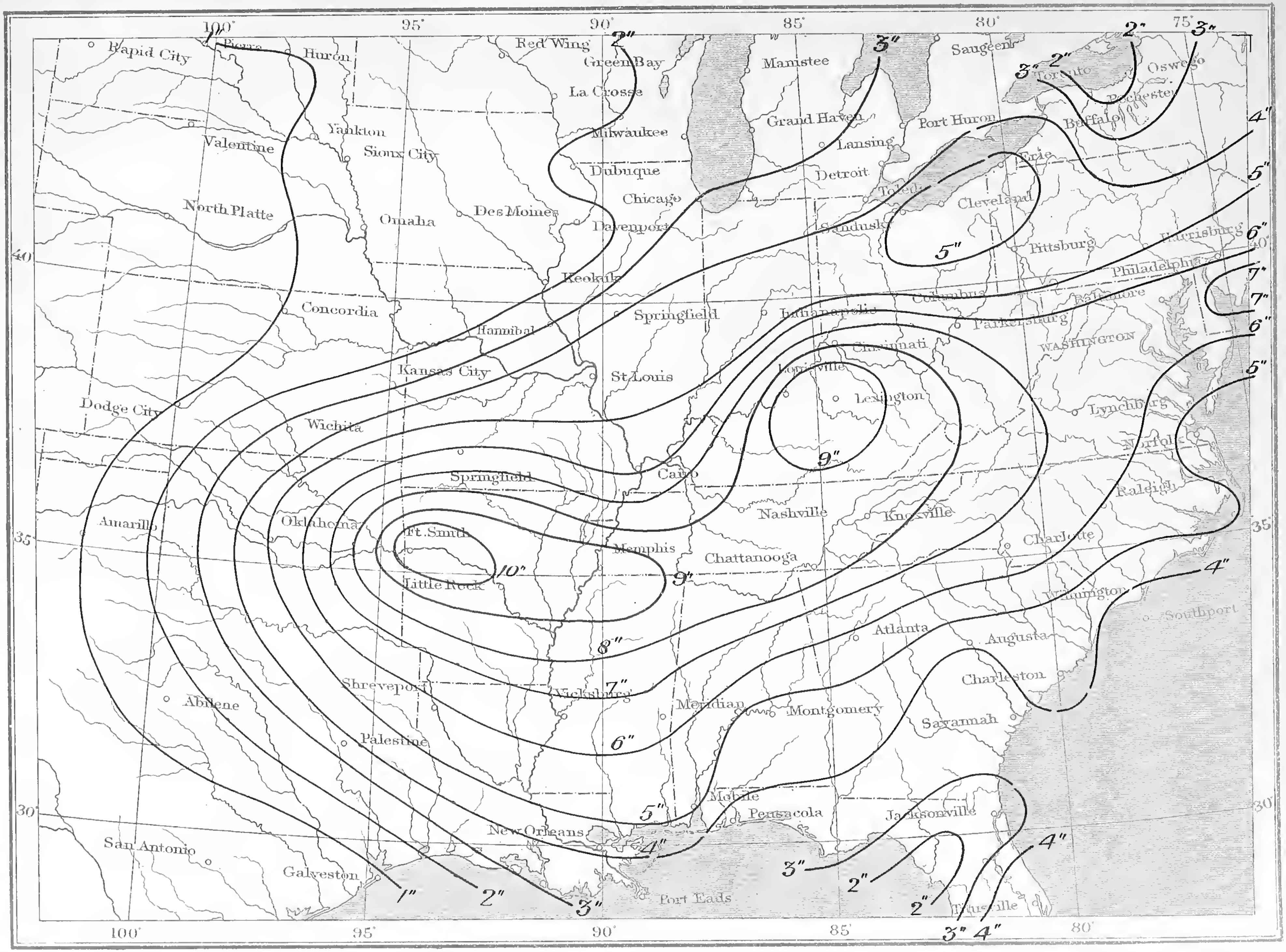
HYDROGRAPHS FOR FLOOD OF 1883.



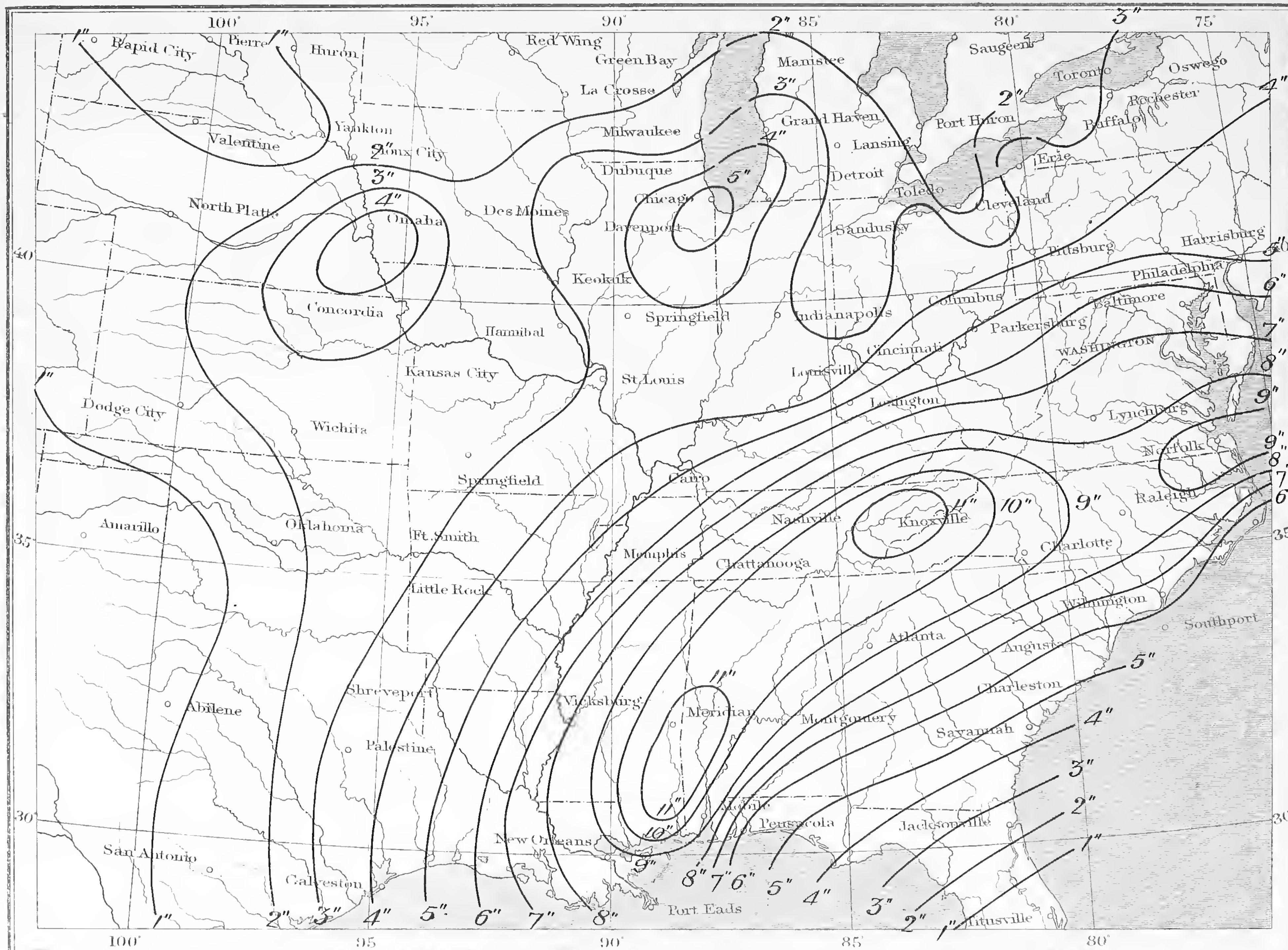
PRECIPITATION FOR JANUARY, 1884.



PRECIPITATION FOR FEBRUARY, 1884.

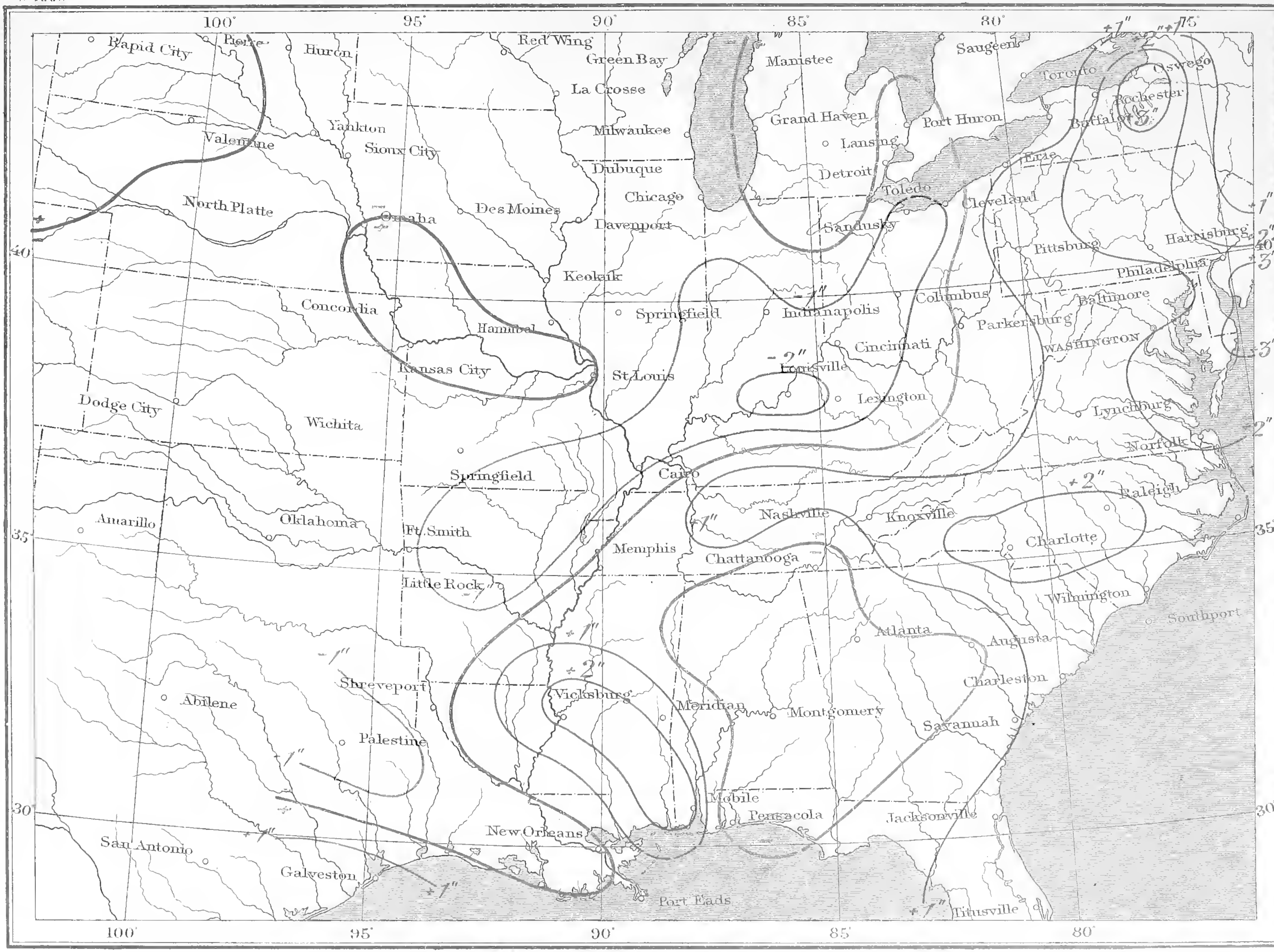


PRECIPITATION FOR MARCH, 1884.

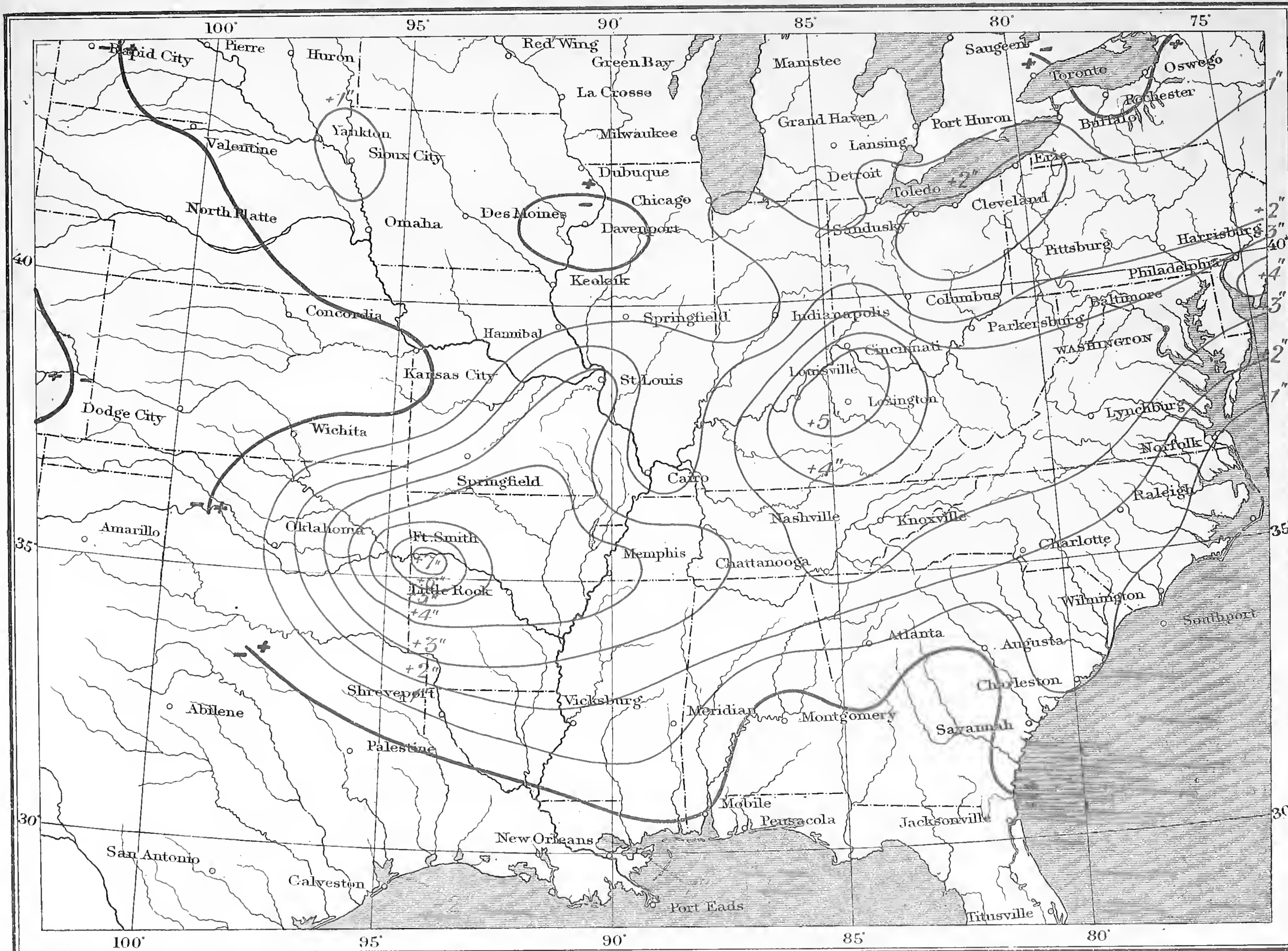


[illegible]

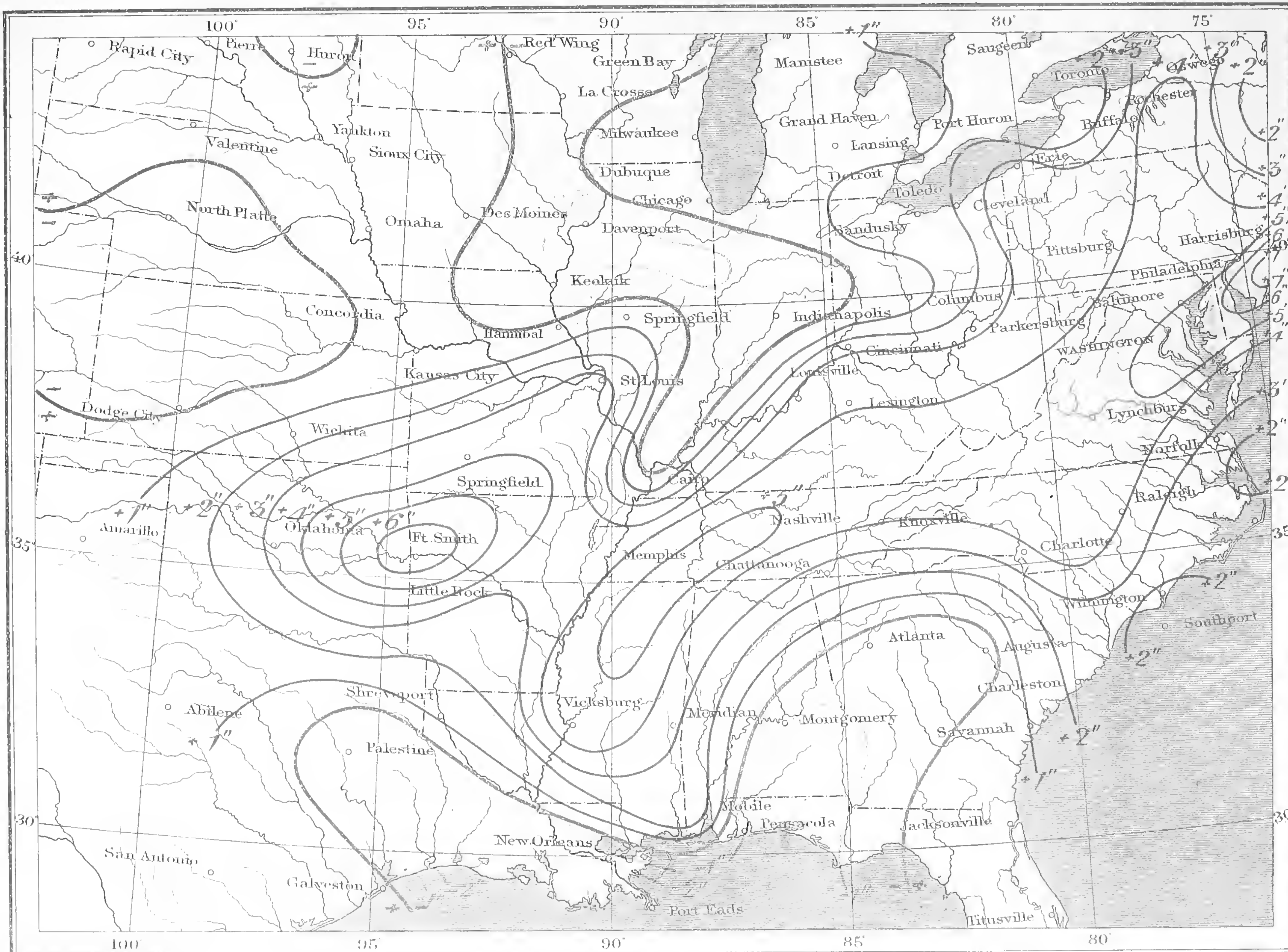
DEPARTURE FROM NORMAL PRECIPITATION. JANUARY. 1884



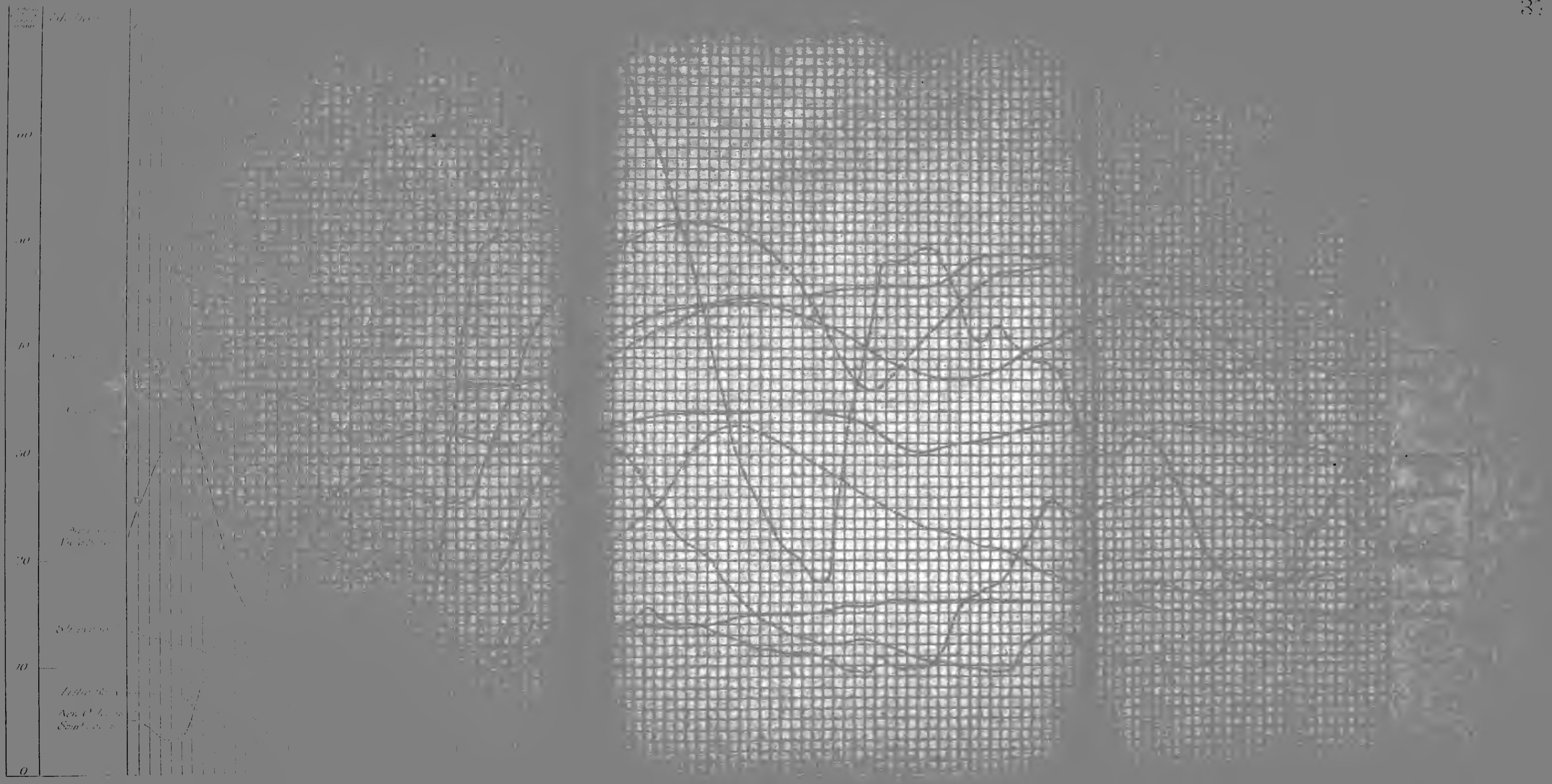
DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY, 1884.

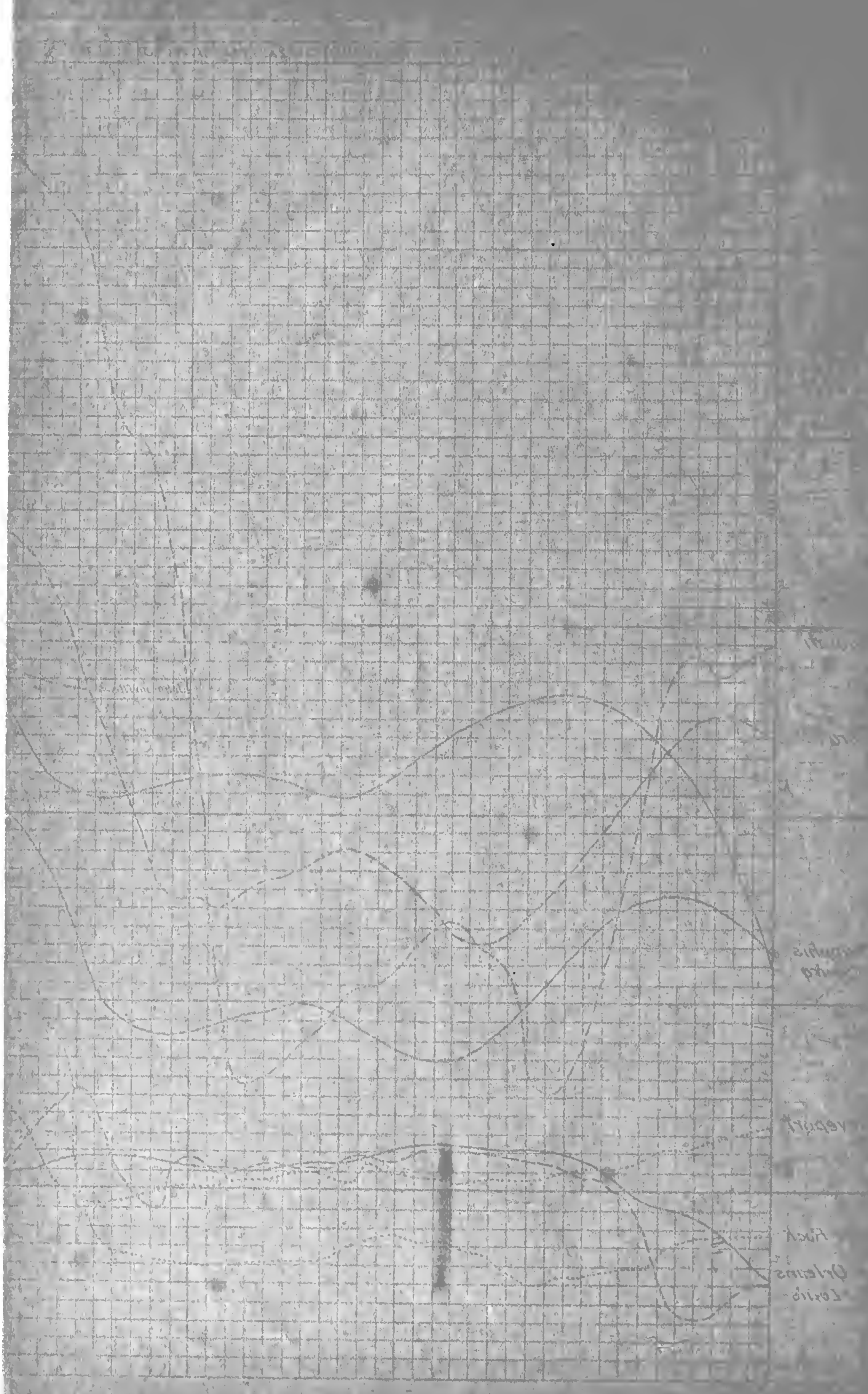


DEPARTURE FROM NORMAL PRECIPITATION, JANUARY 1 TO FEBRUARY 29, 1884.

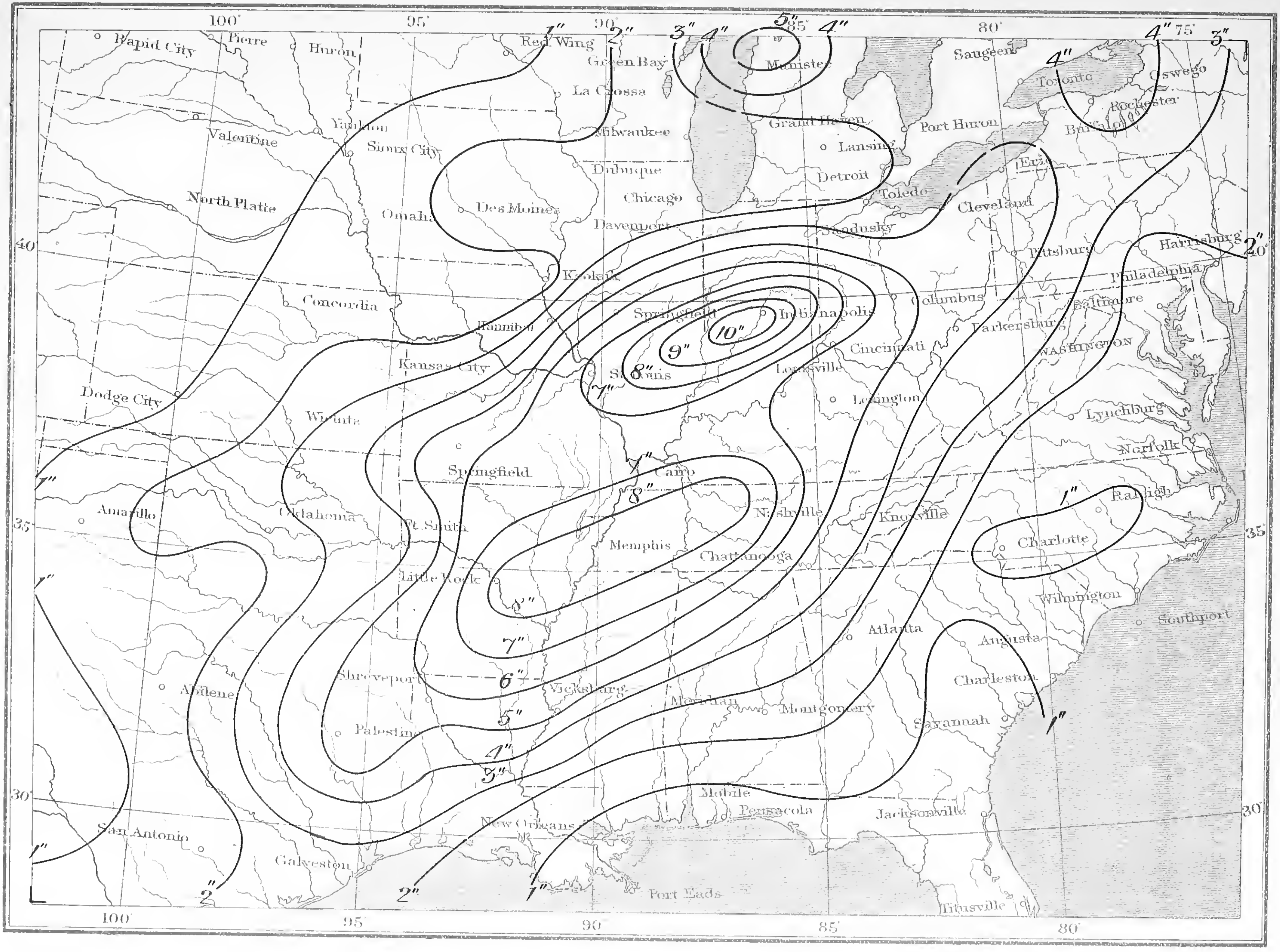


Pl. XXXVII

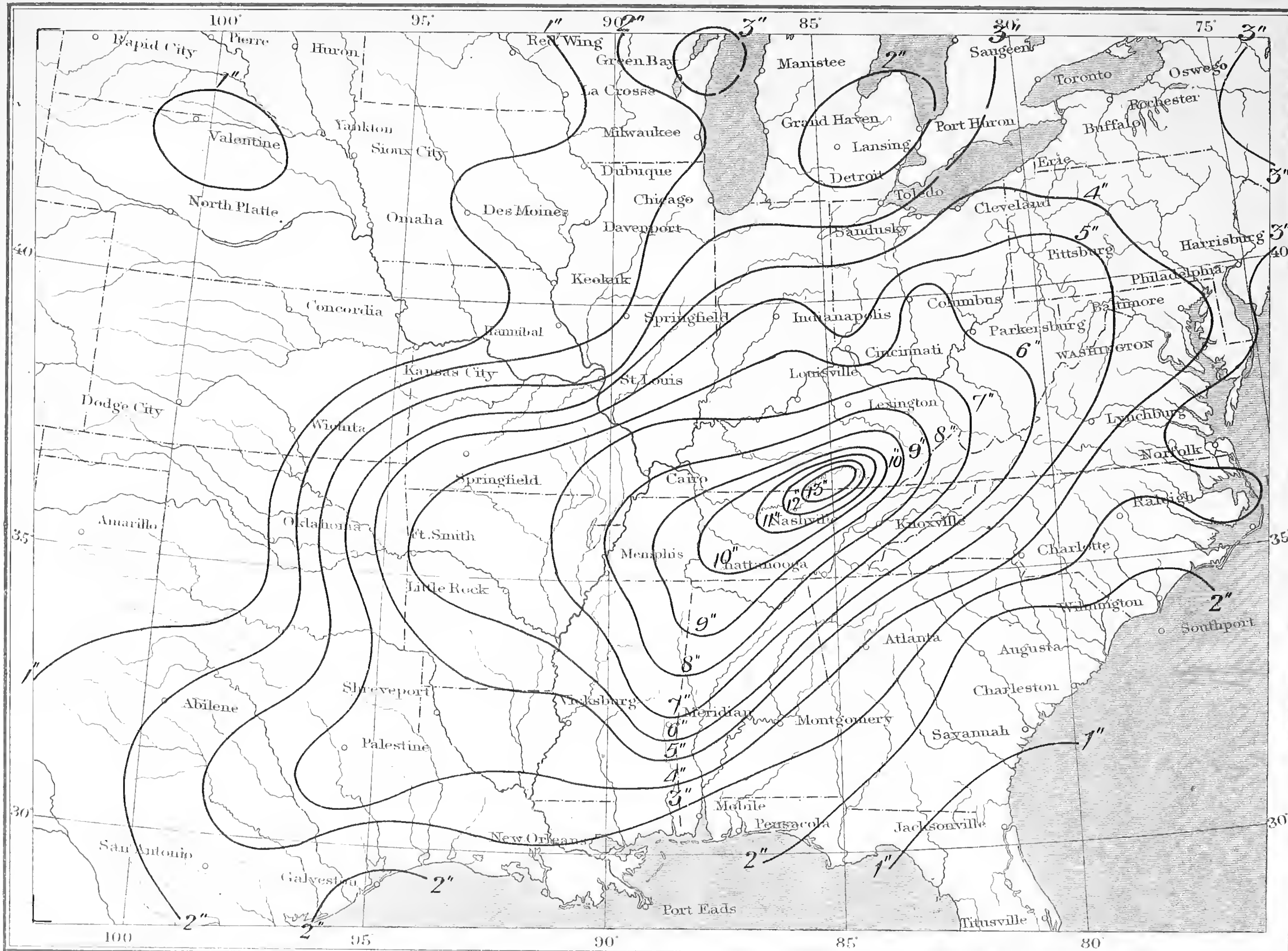




PRECIPITATION FOR JANUARY, 1890.

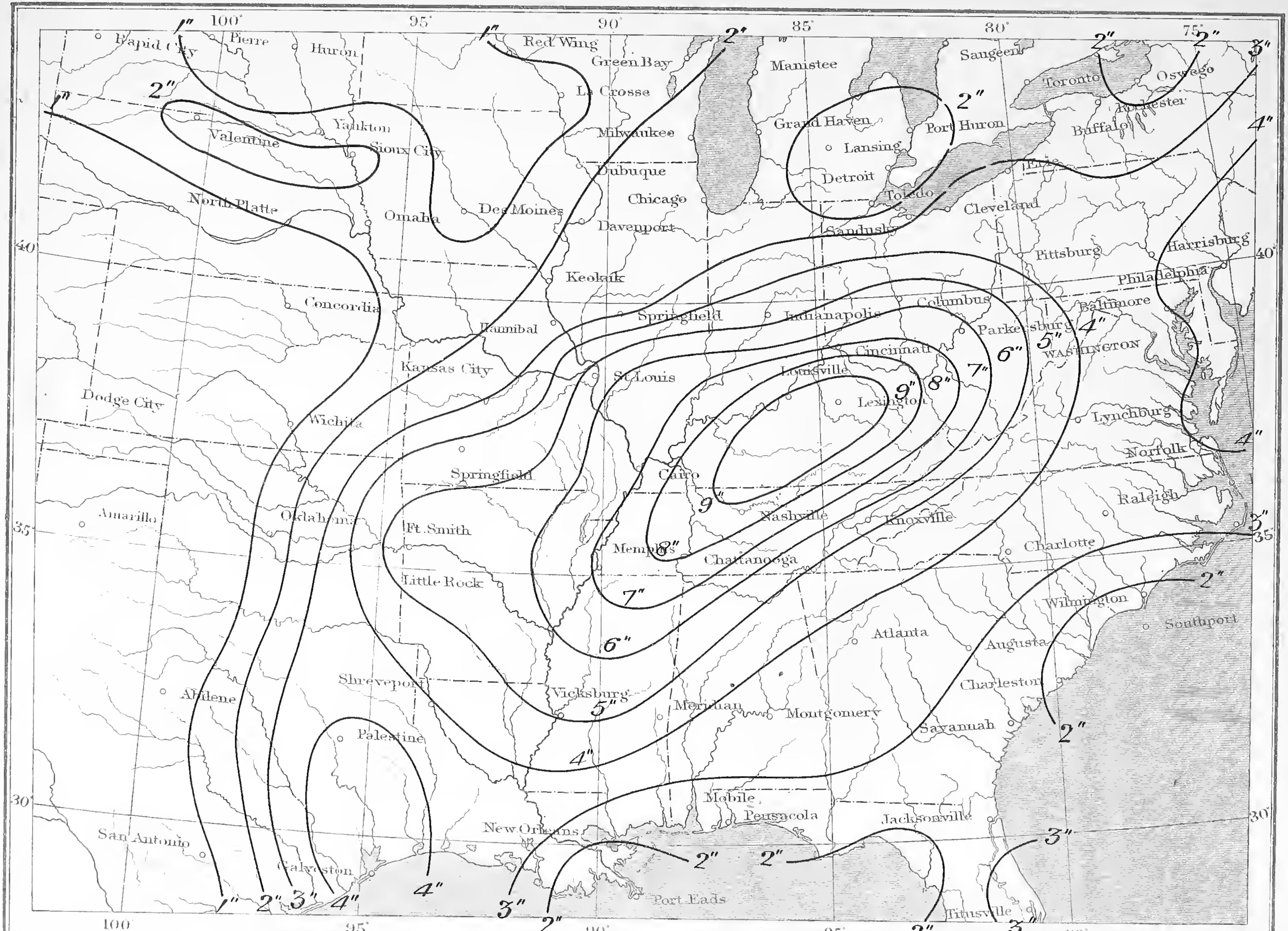


PRECIPITATION FOR FEBRUARY, 1890.

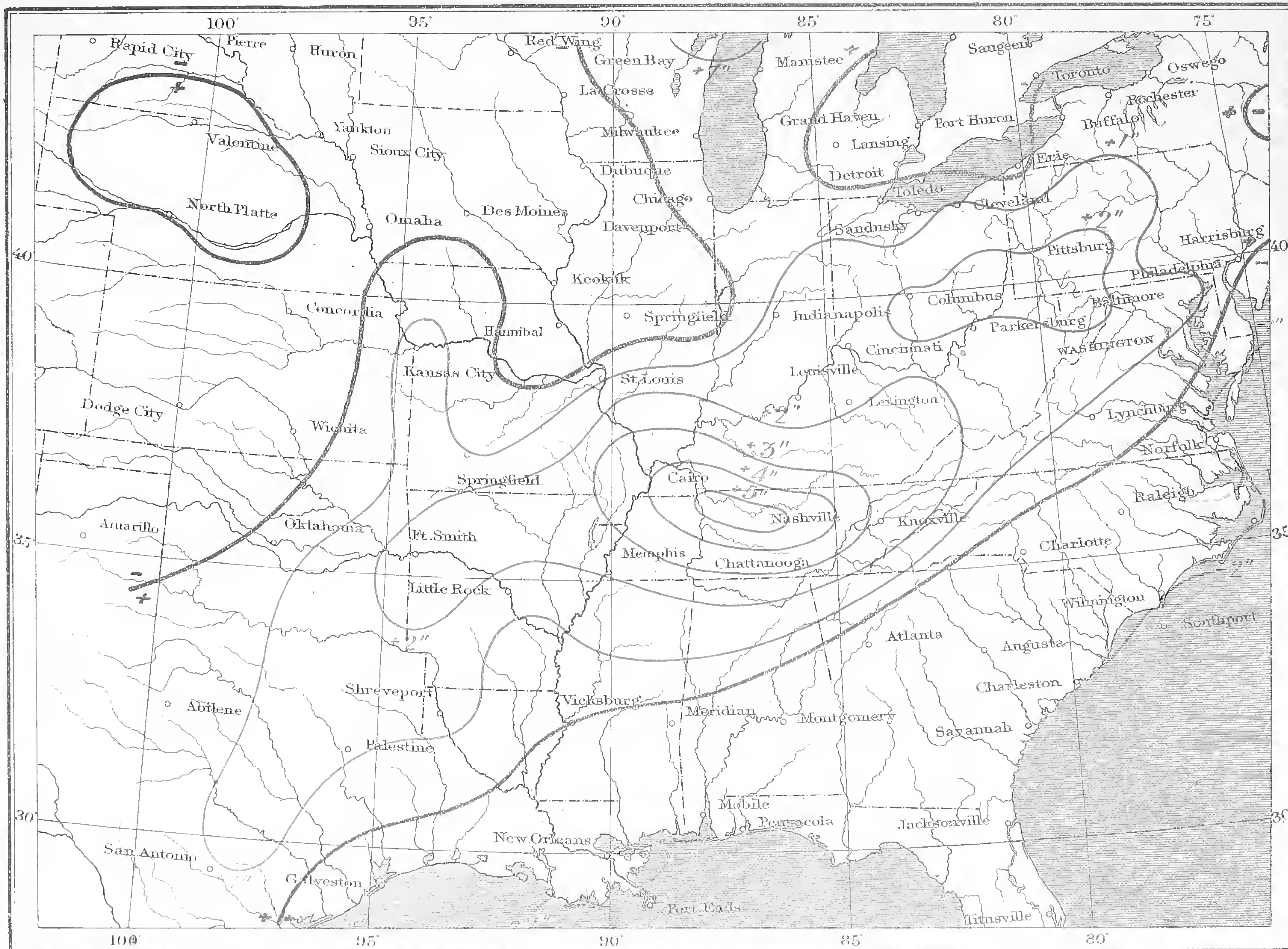


Pl. XL.

PRECIPITATION FOR MARCH, 1890.

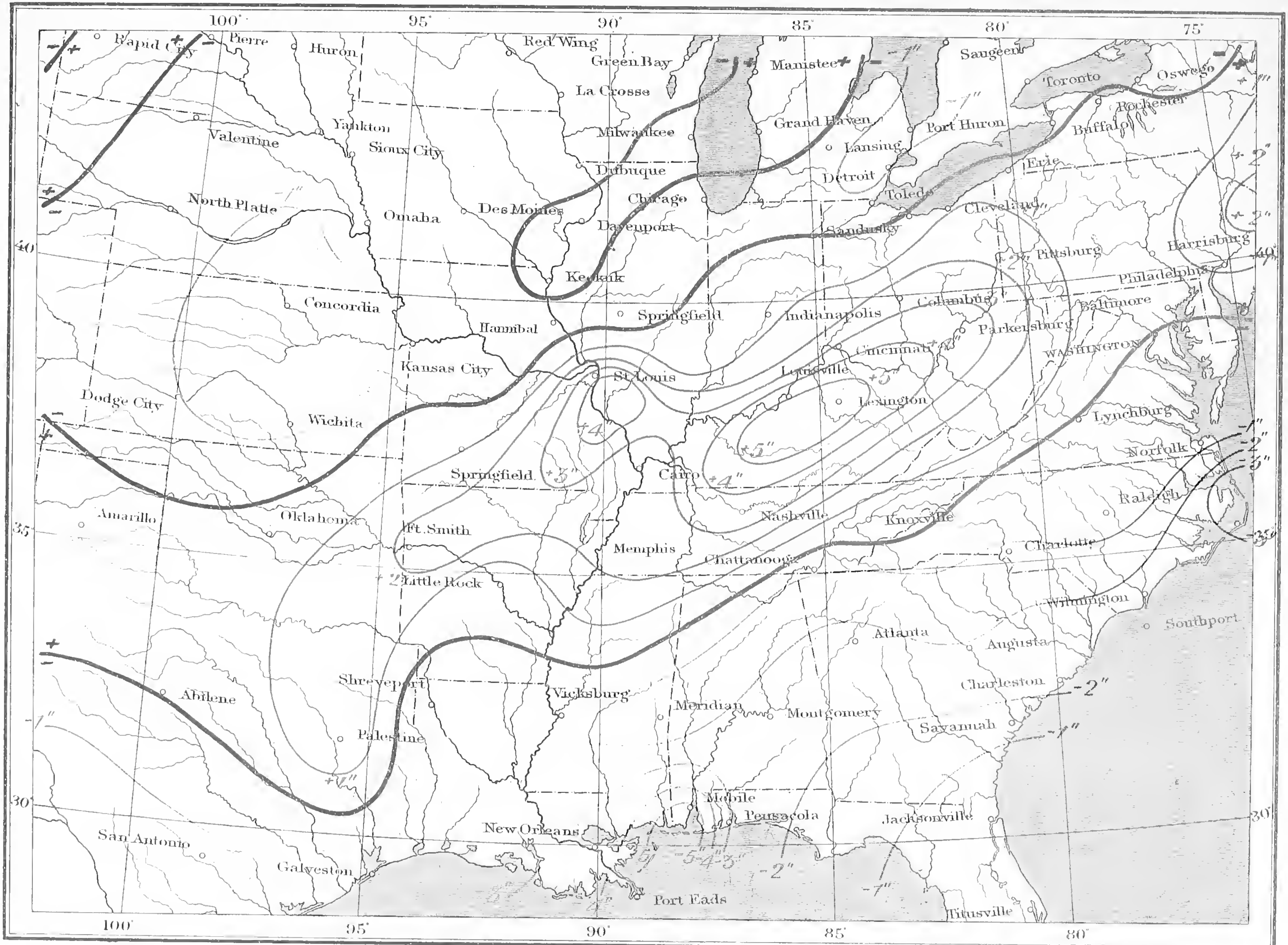


DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY, 1890.

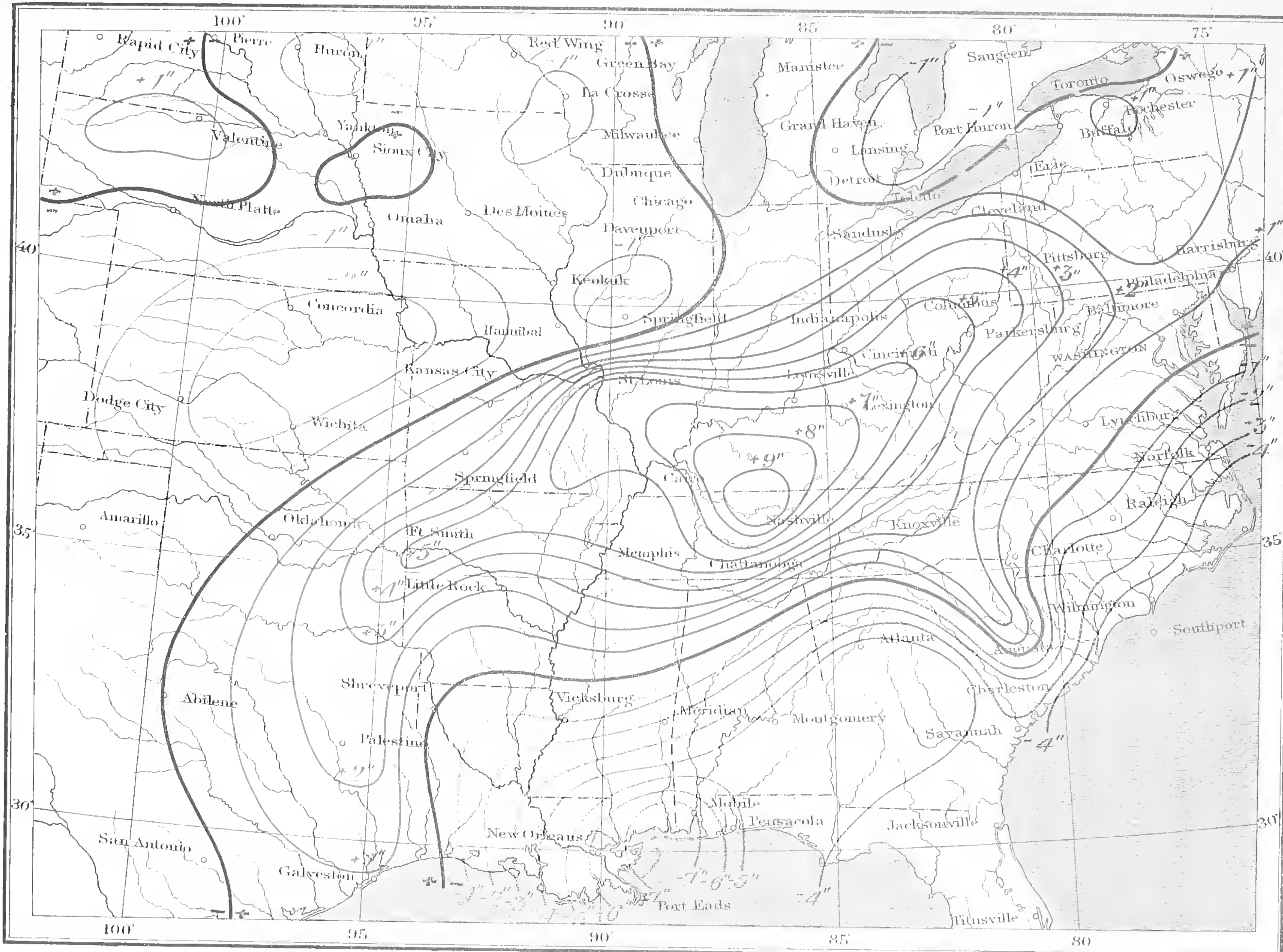


PI. XLII.

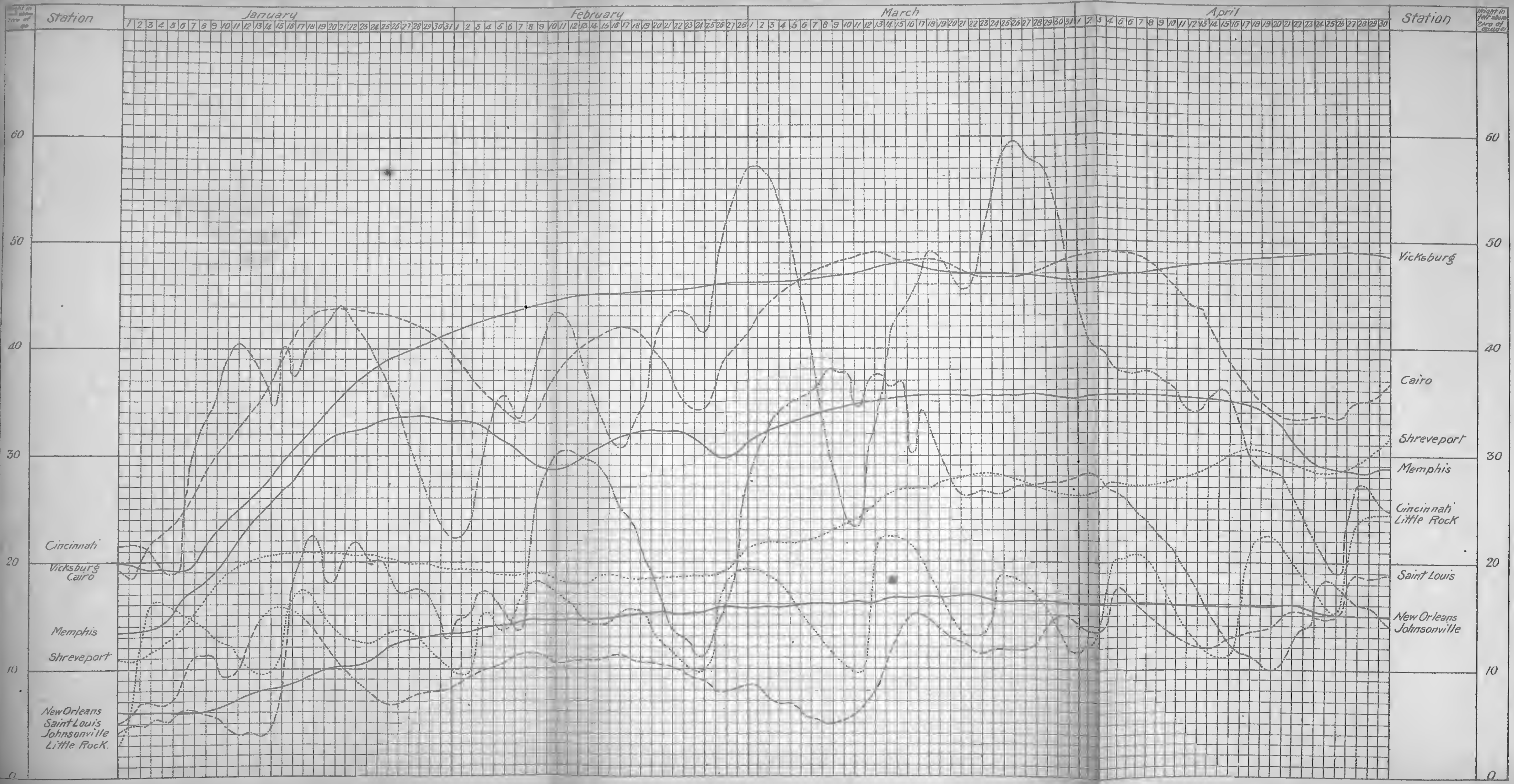
DEPARTURE FROM NORMAL PRECIPITATION, MARCH, 1890.



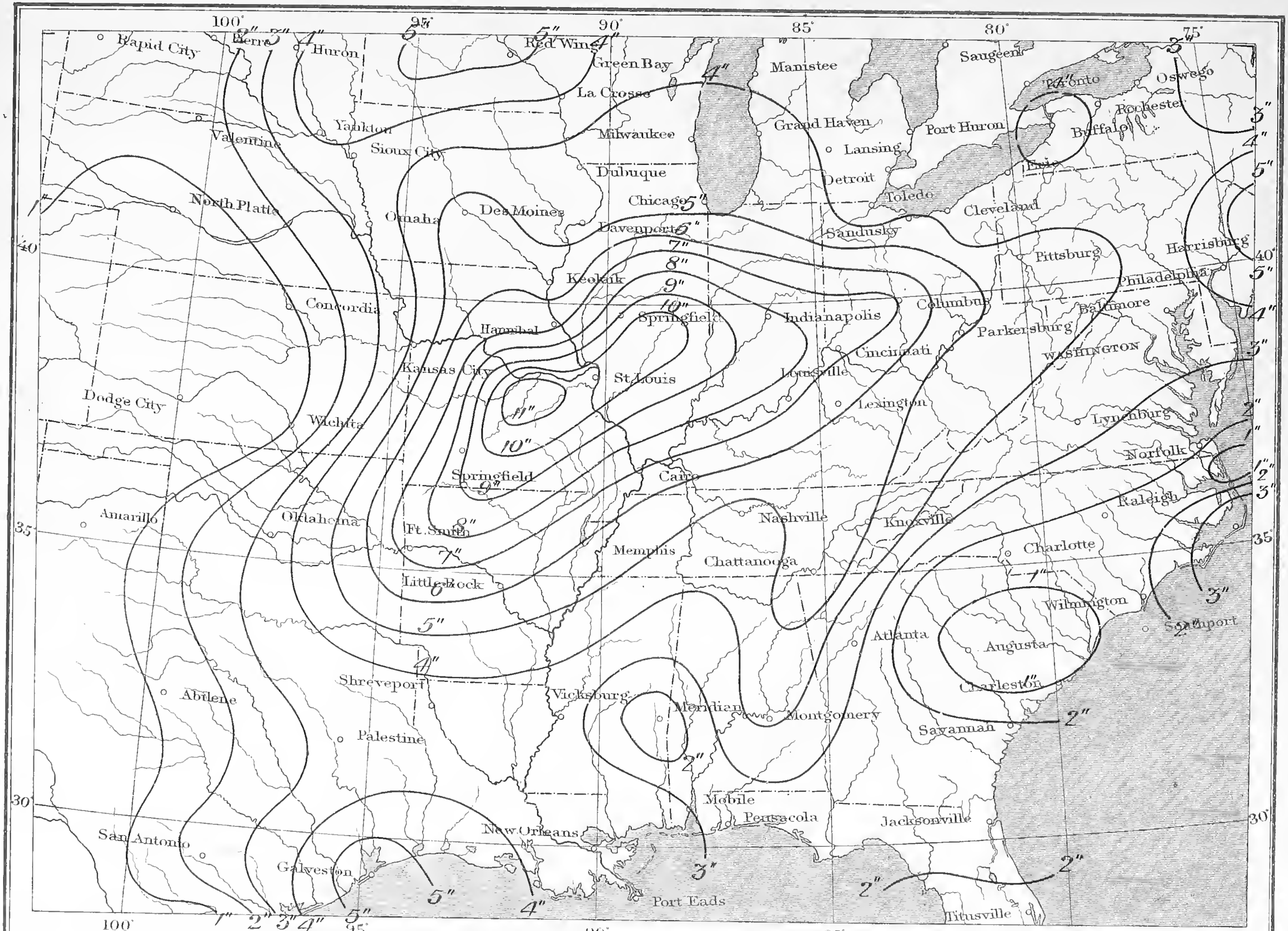
DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY 1 TO MARCH 31, 1890.



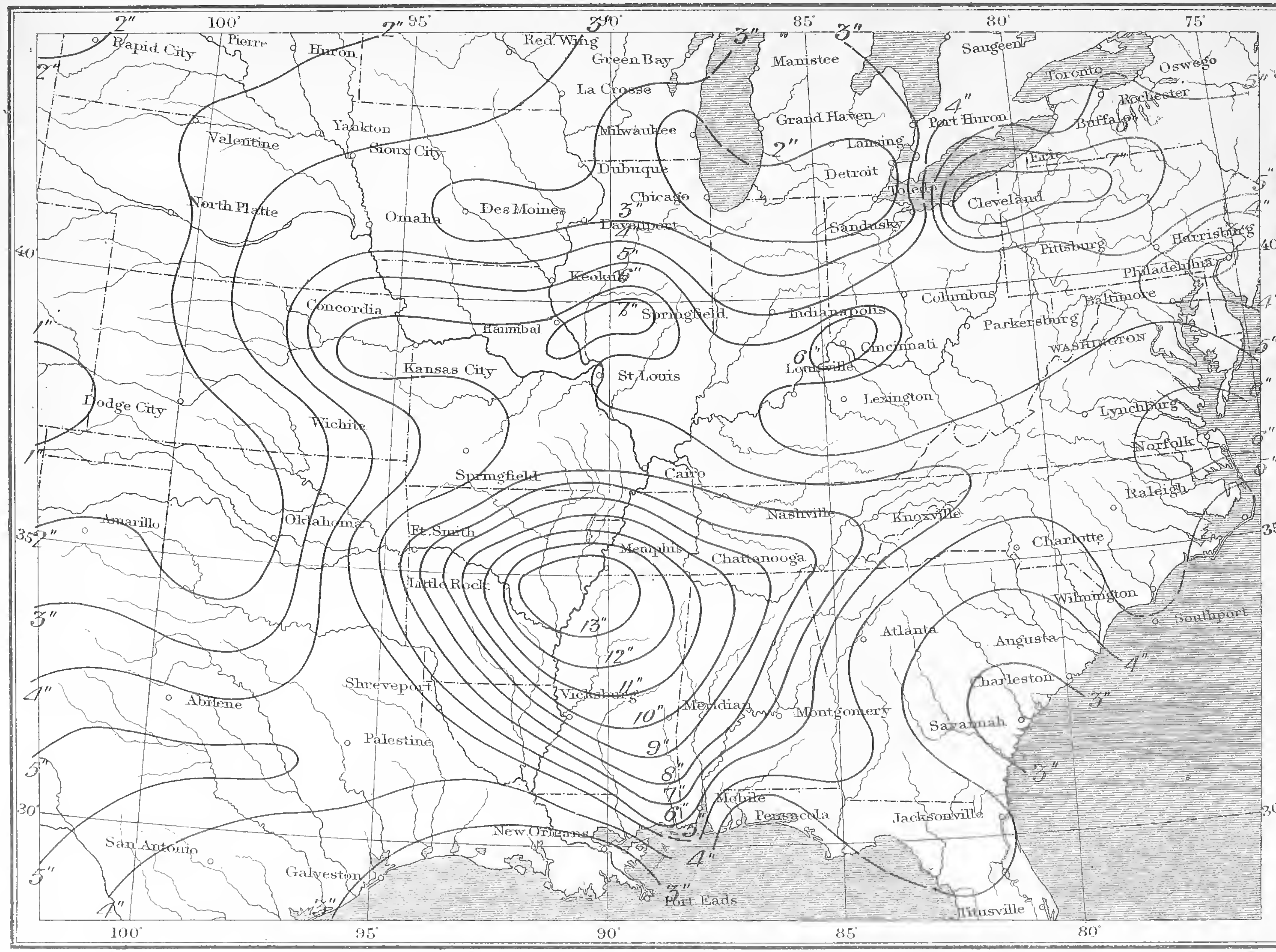
HYDROGRAPHS FOR FLOOD OF 1890.



PRECIPITATION FOR APRIL, 1893.

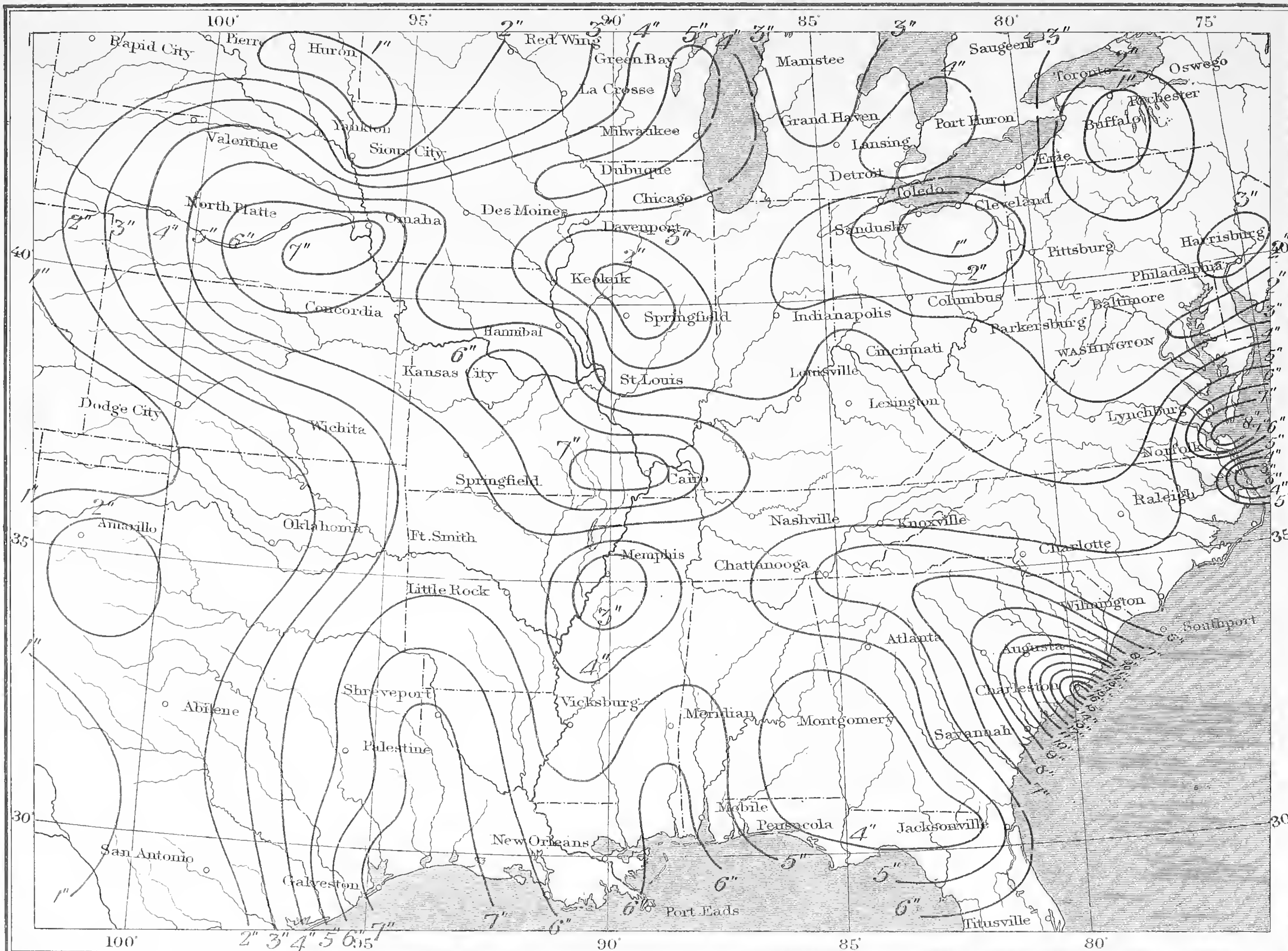


PRECIPITATION FOR MAY, 1893.



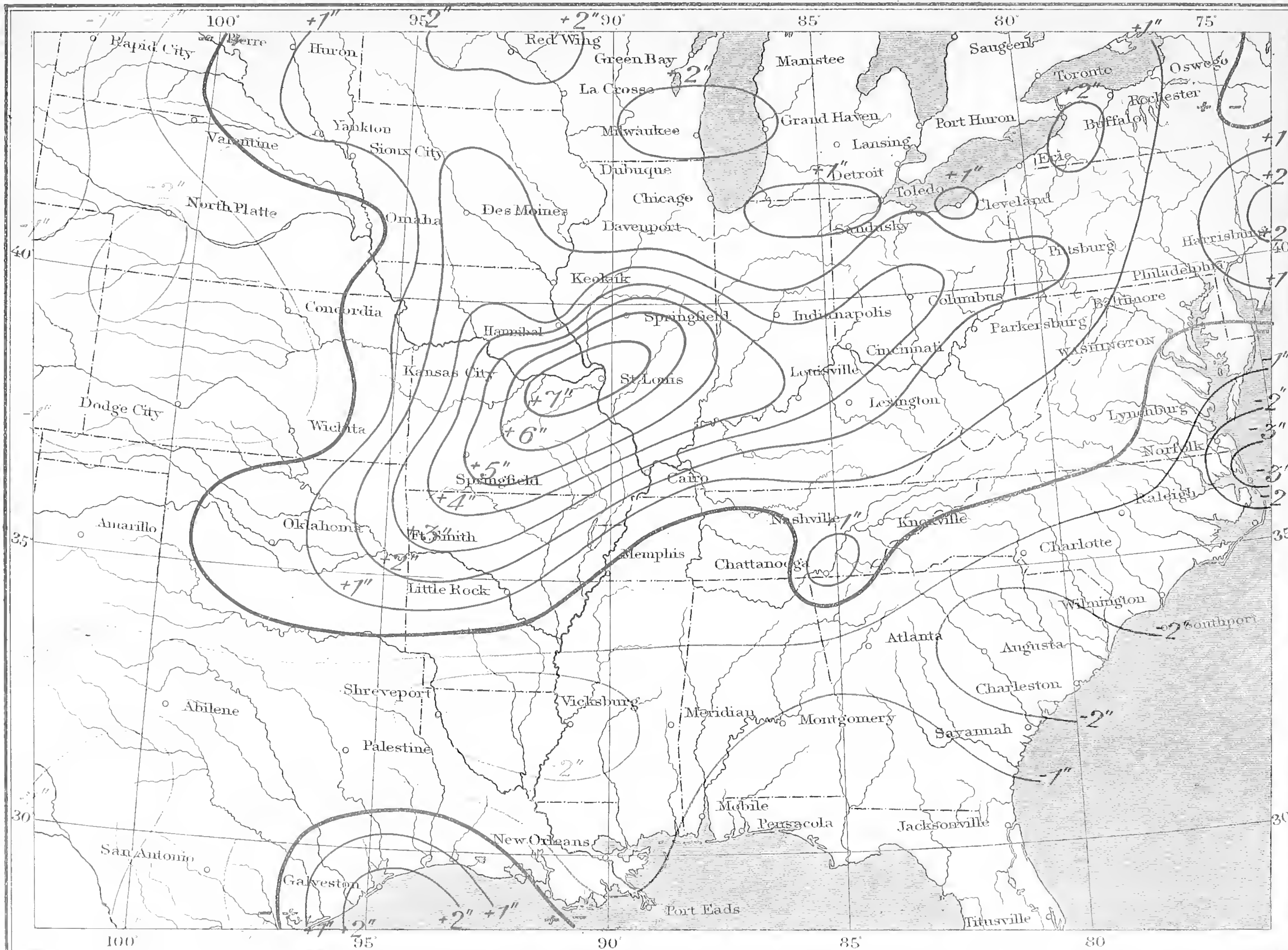
Pl. XLVII.

PRECIPITATION FOR JUNE, 1893.



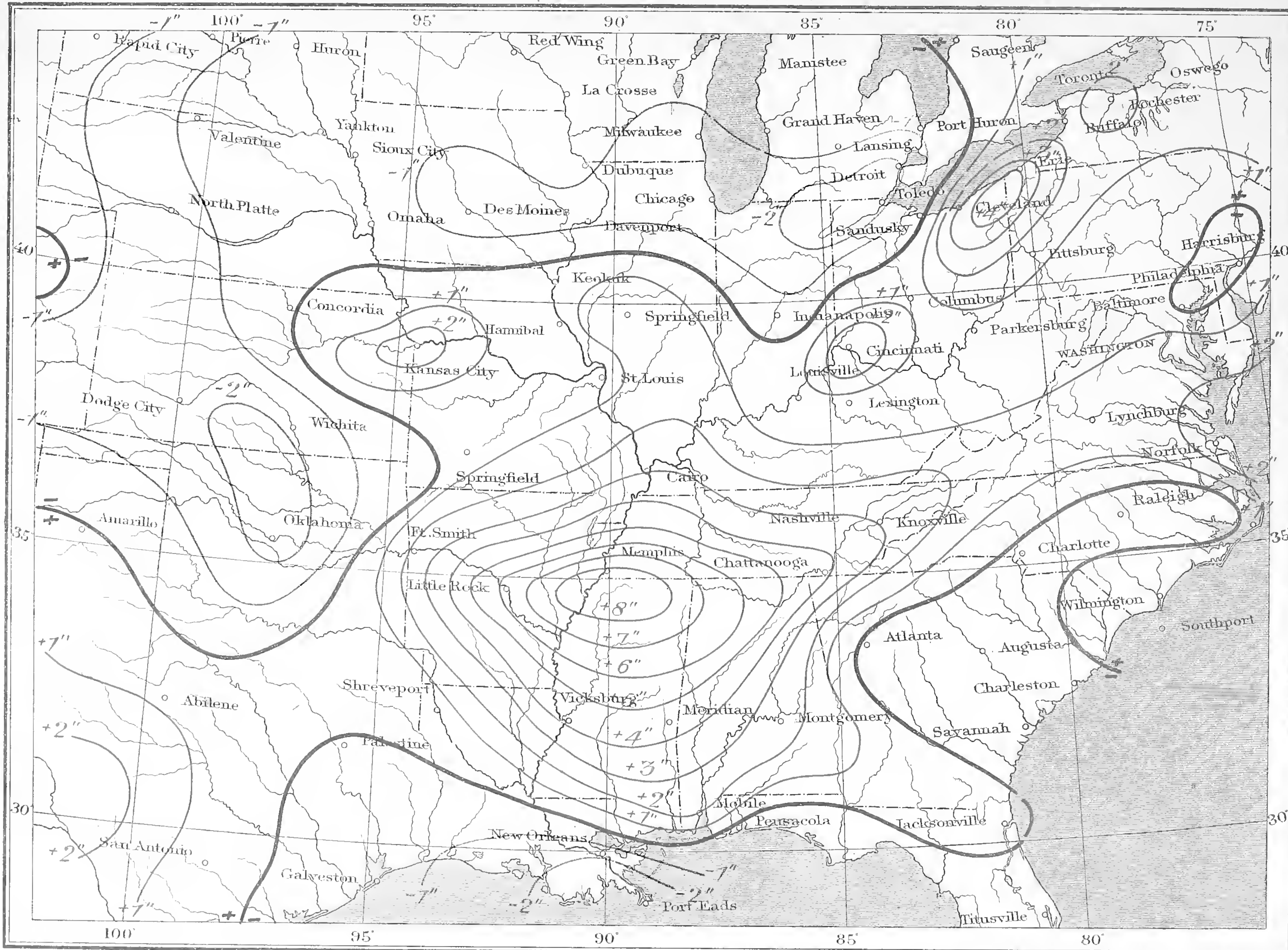
Pl. XLVIII.

DEPARTURE FROM NORMAL PRECIPITATION, APRIL, 1893.



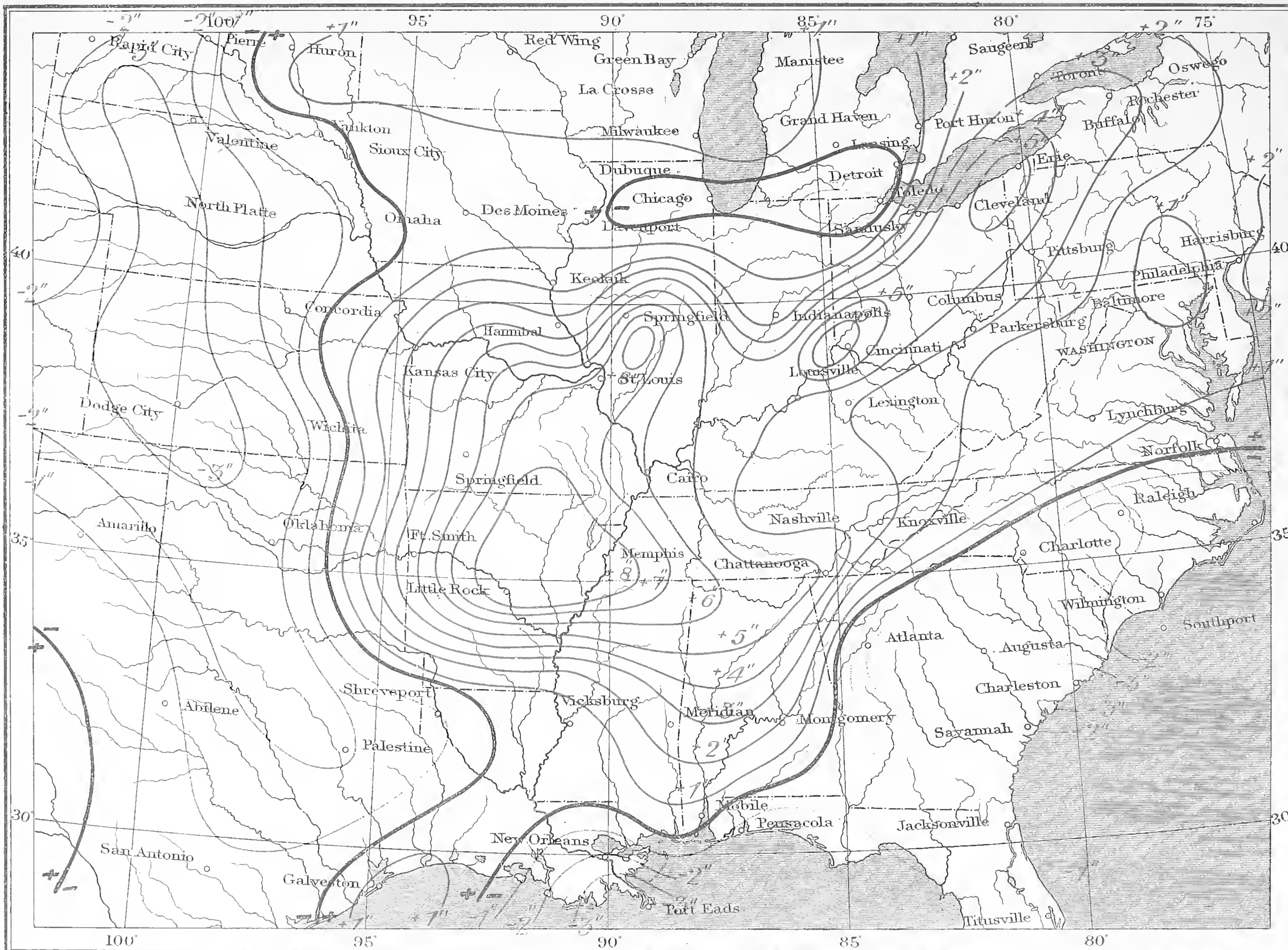
Pl. XLIX.

DEPARTURE FROM NORMAL PRECIPITATION, MAY, 1893.

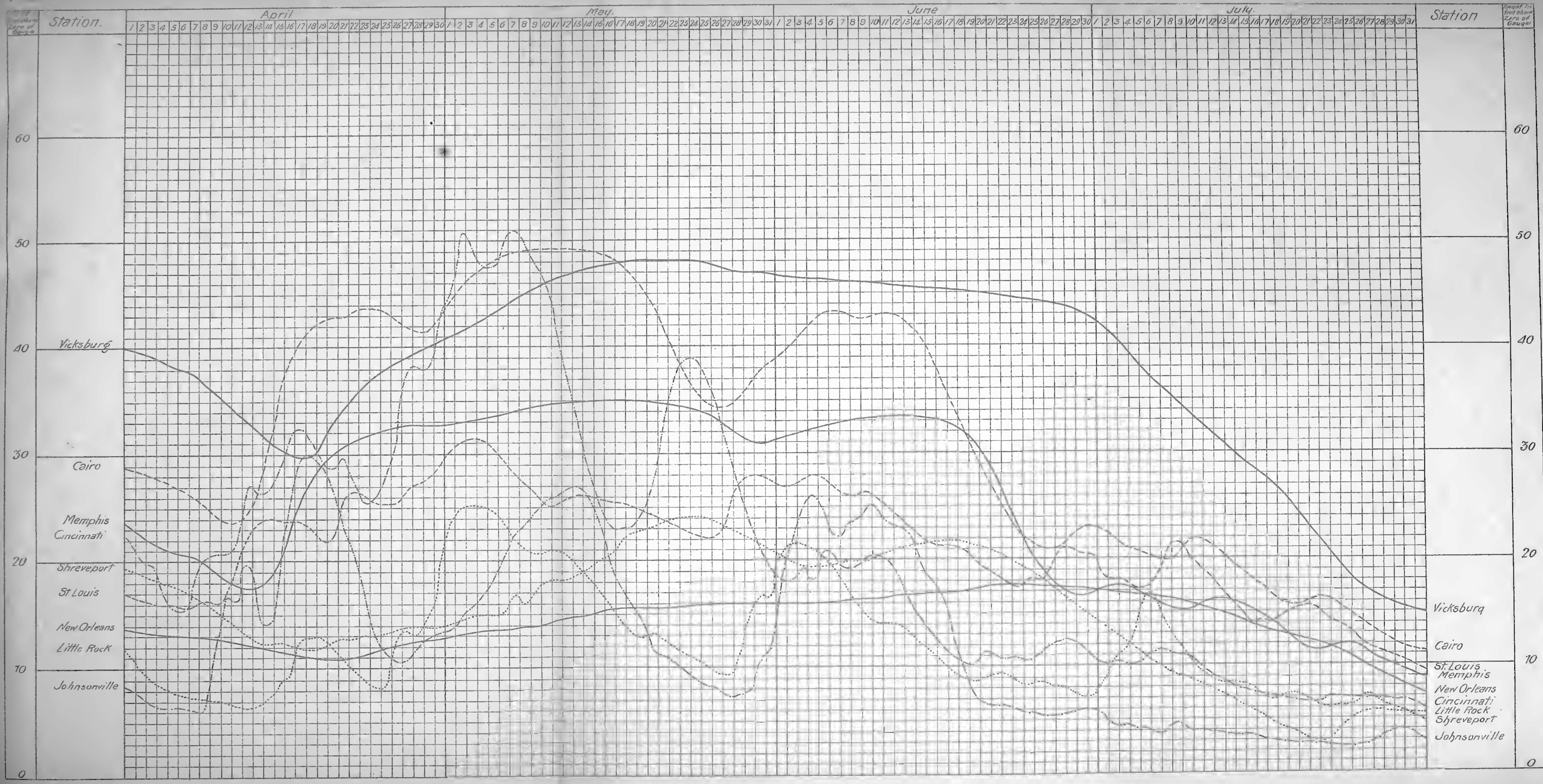


Pl. L.

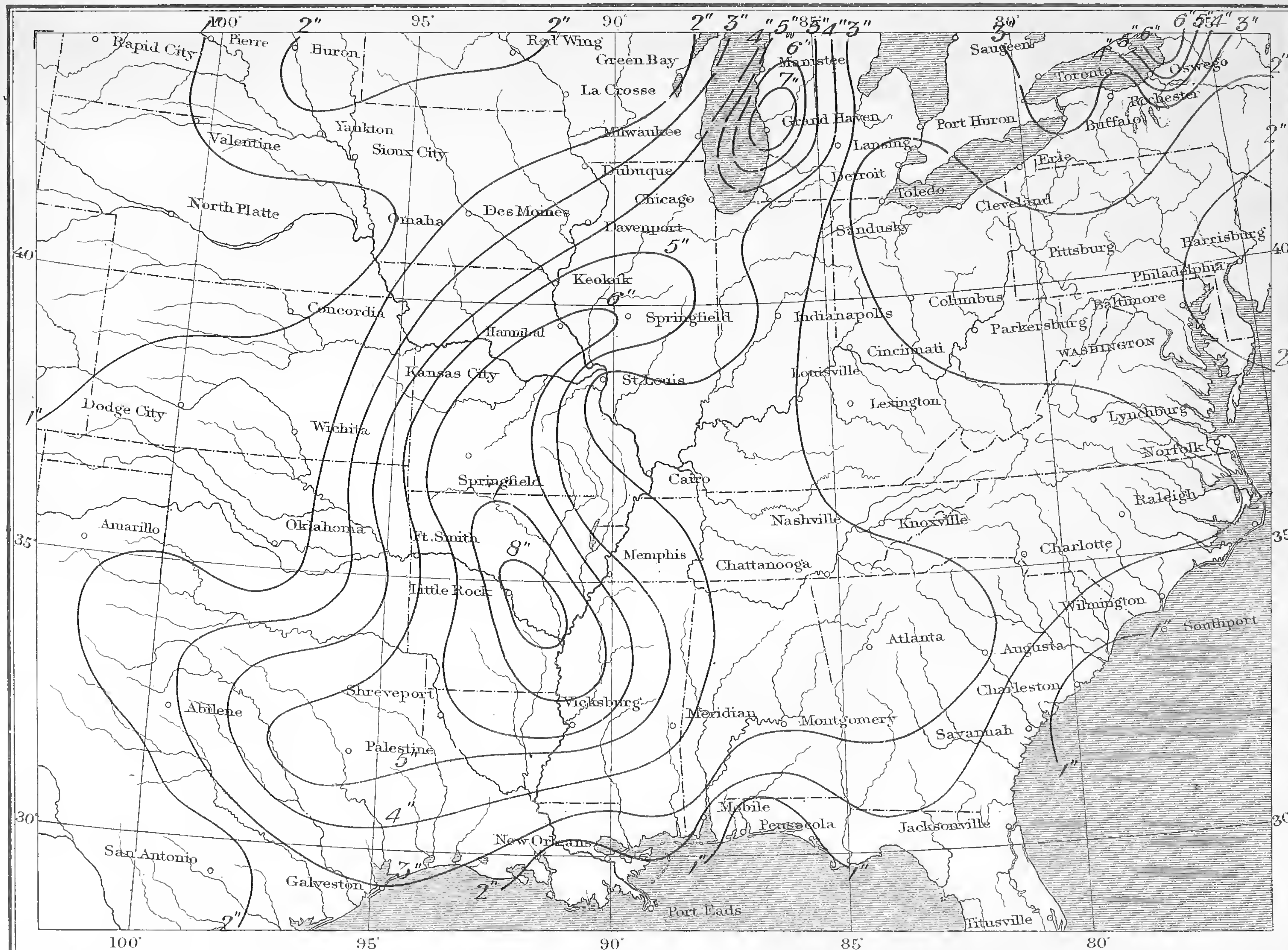
DEPARTURE FROM NORMAL PRECIPITATION, APRIL 1 TO MAY 31, 1893.



HYDROGRAPHS FOR FLOOD OF 1893.

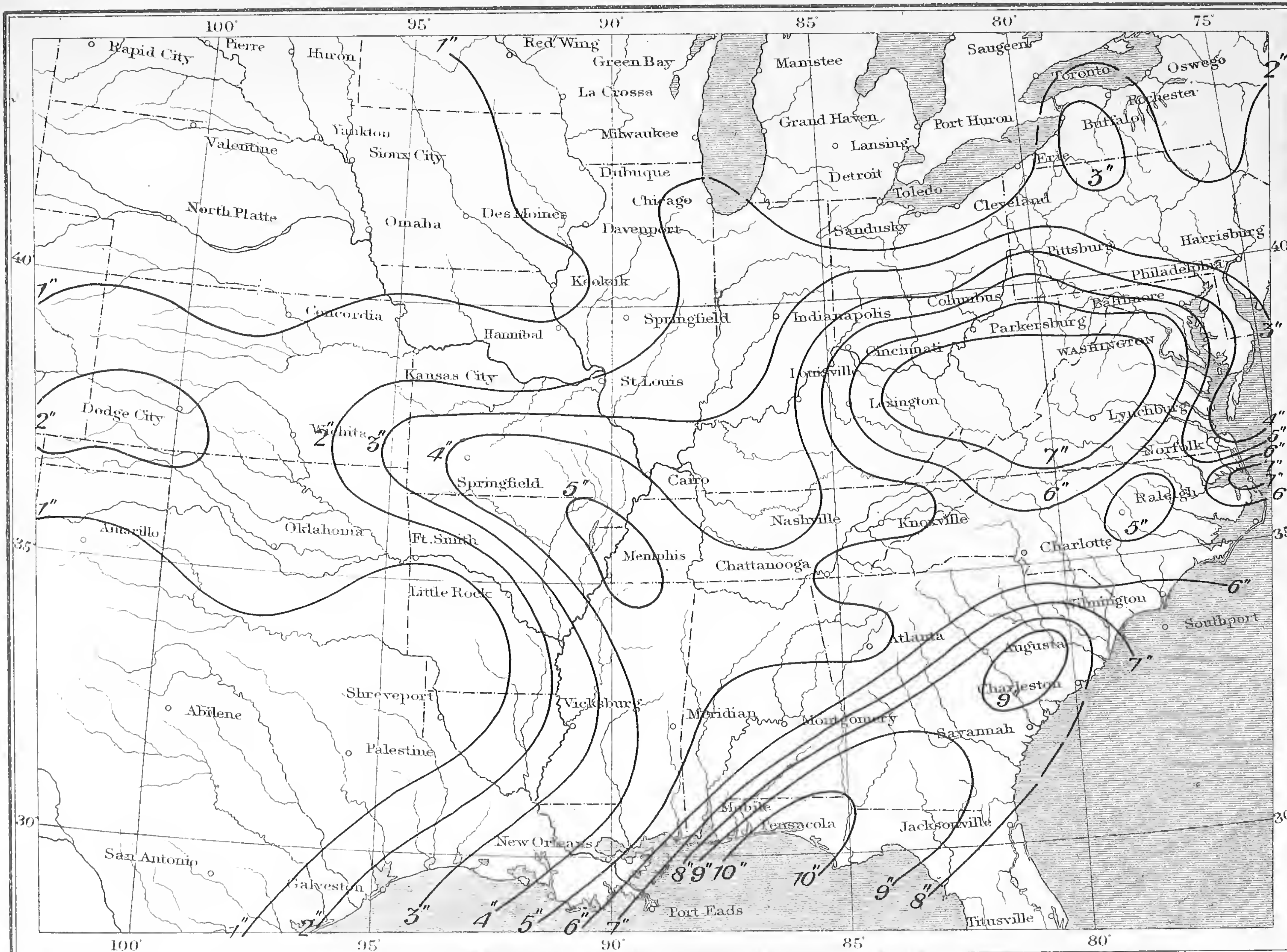


PRECIPITATION FOR JANUARY, 1897.



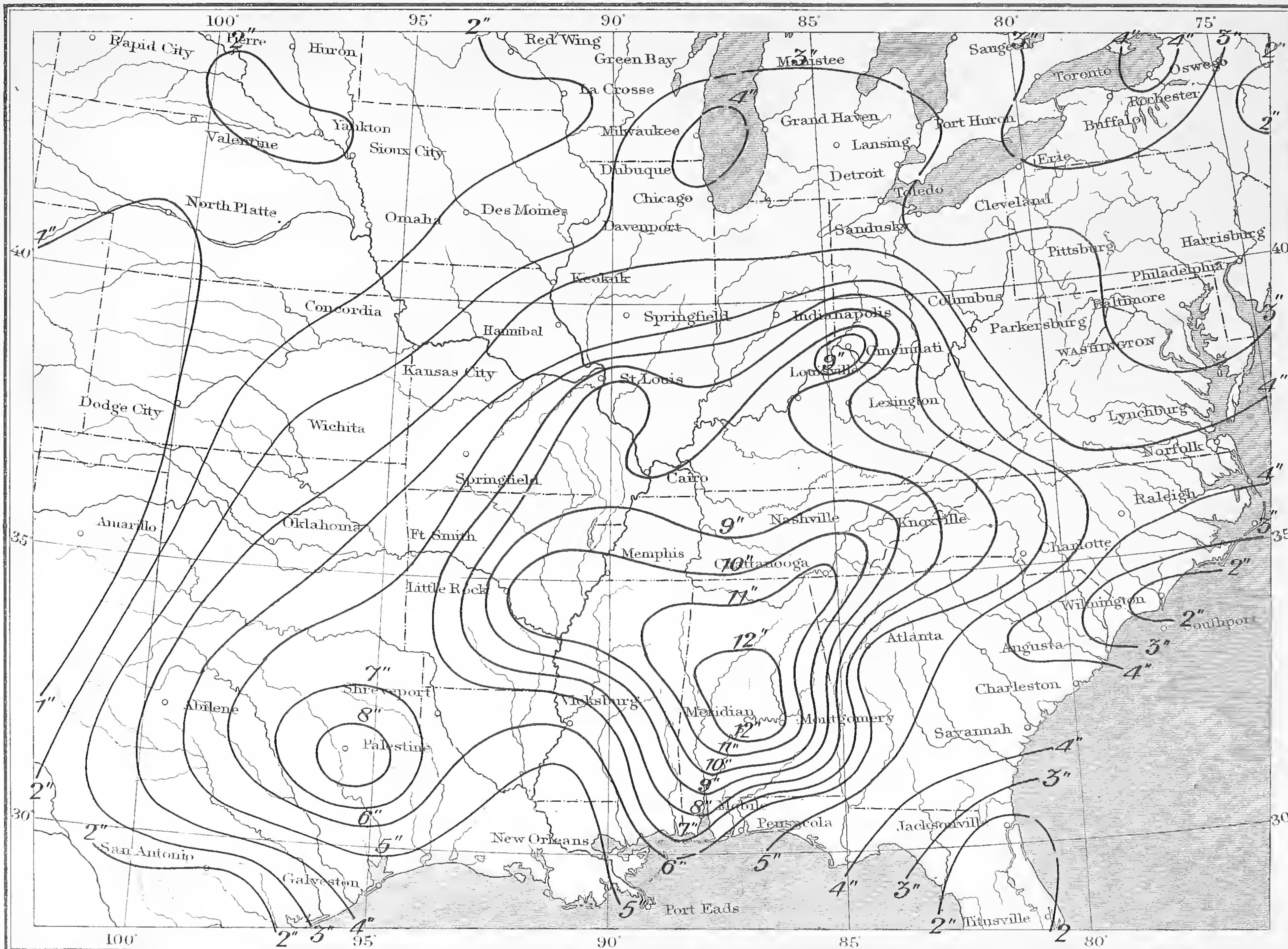
Pl. LIII.

PRECIPITATION FOR FEBRUARY, 1897.

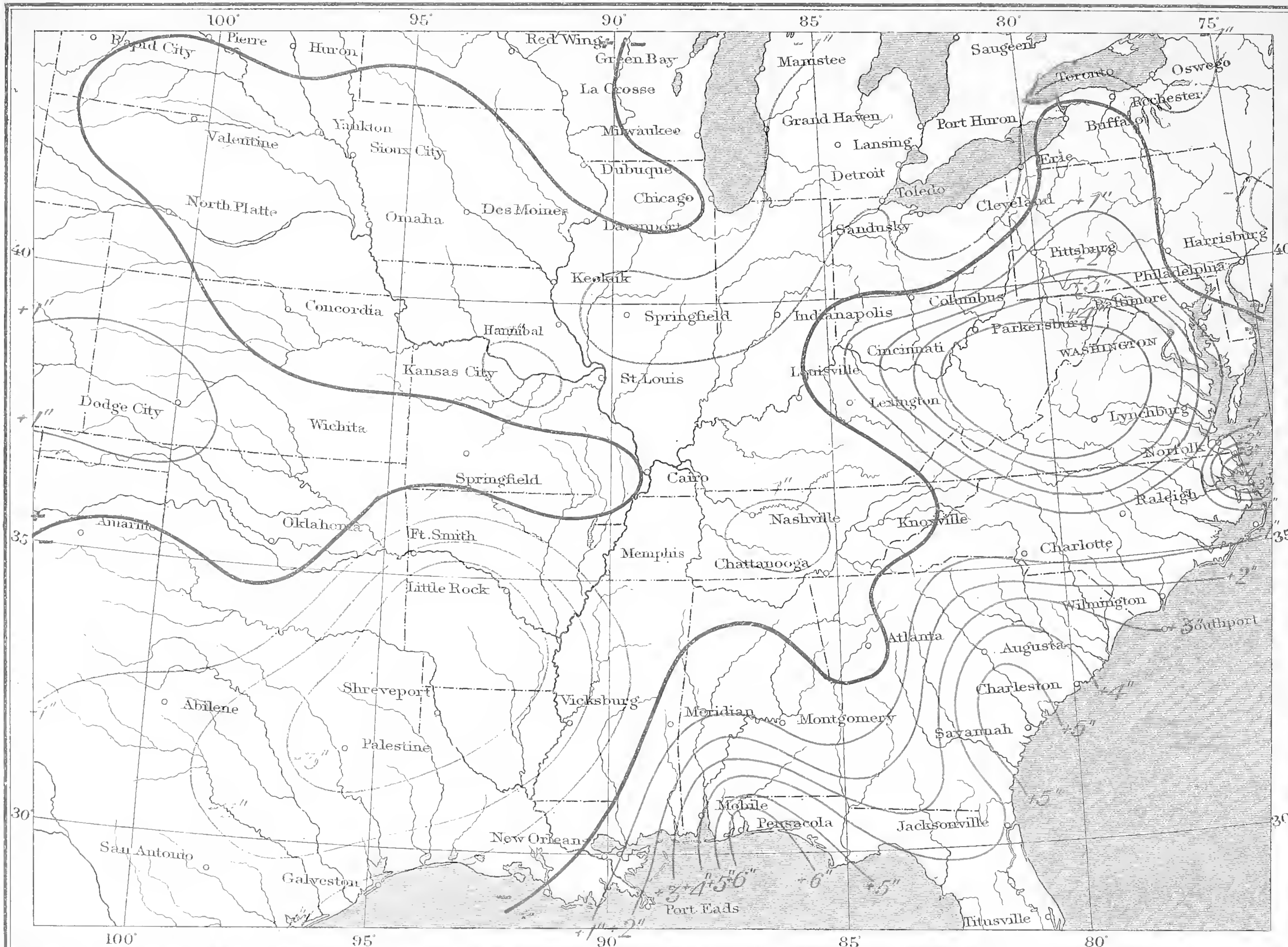


Pl. LIV.

PRECIPITATION FOR MARCH, 1897.

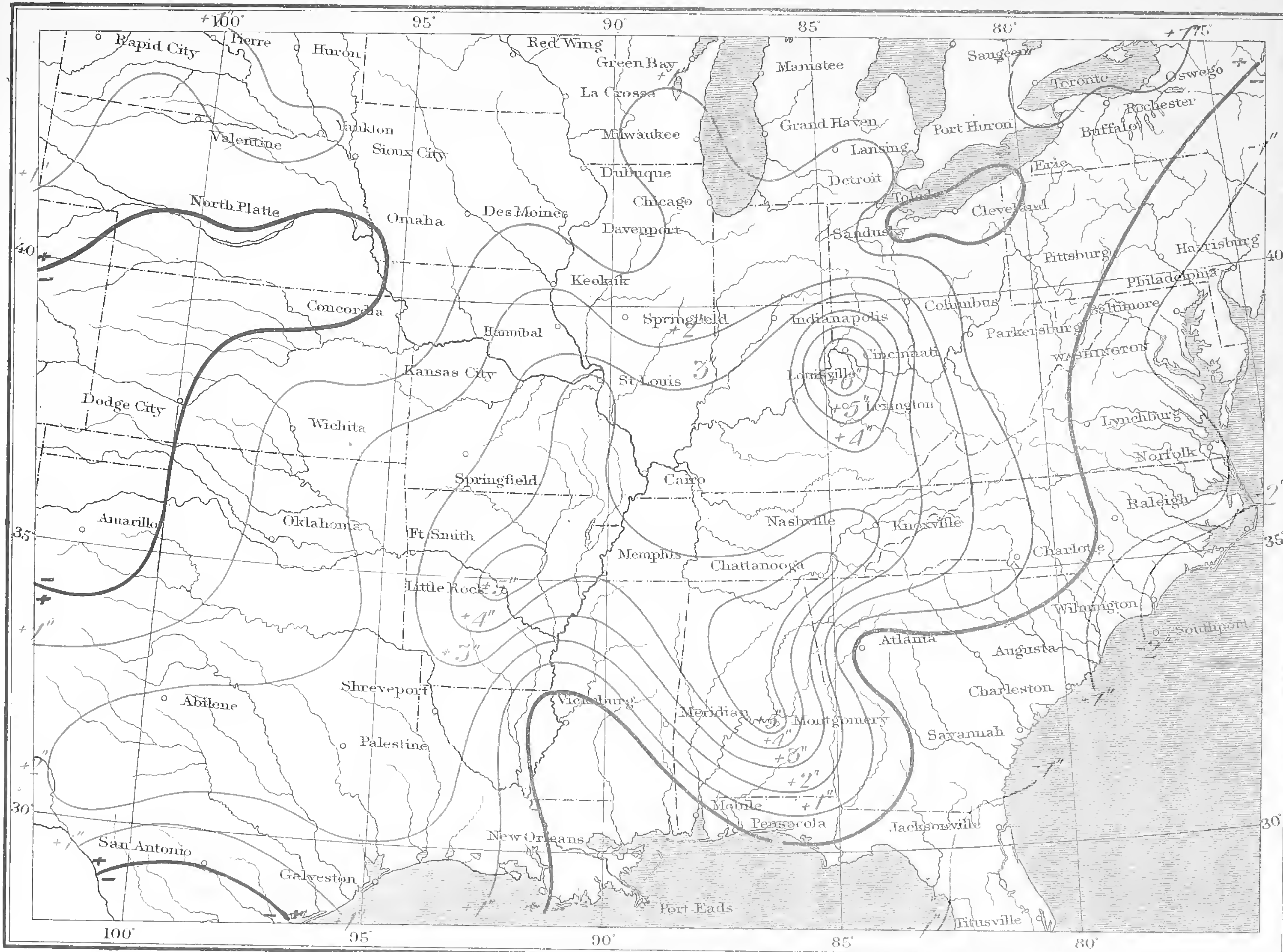


DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY, 1897.

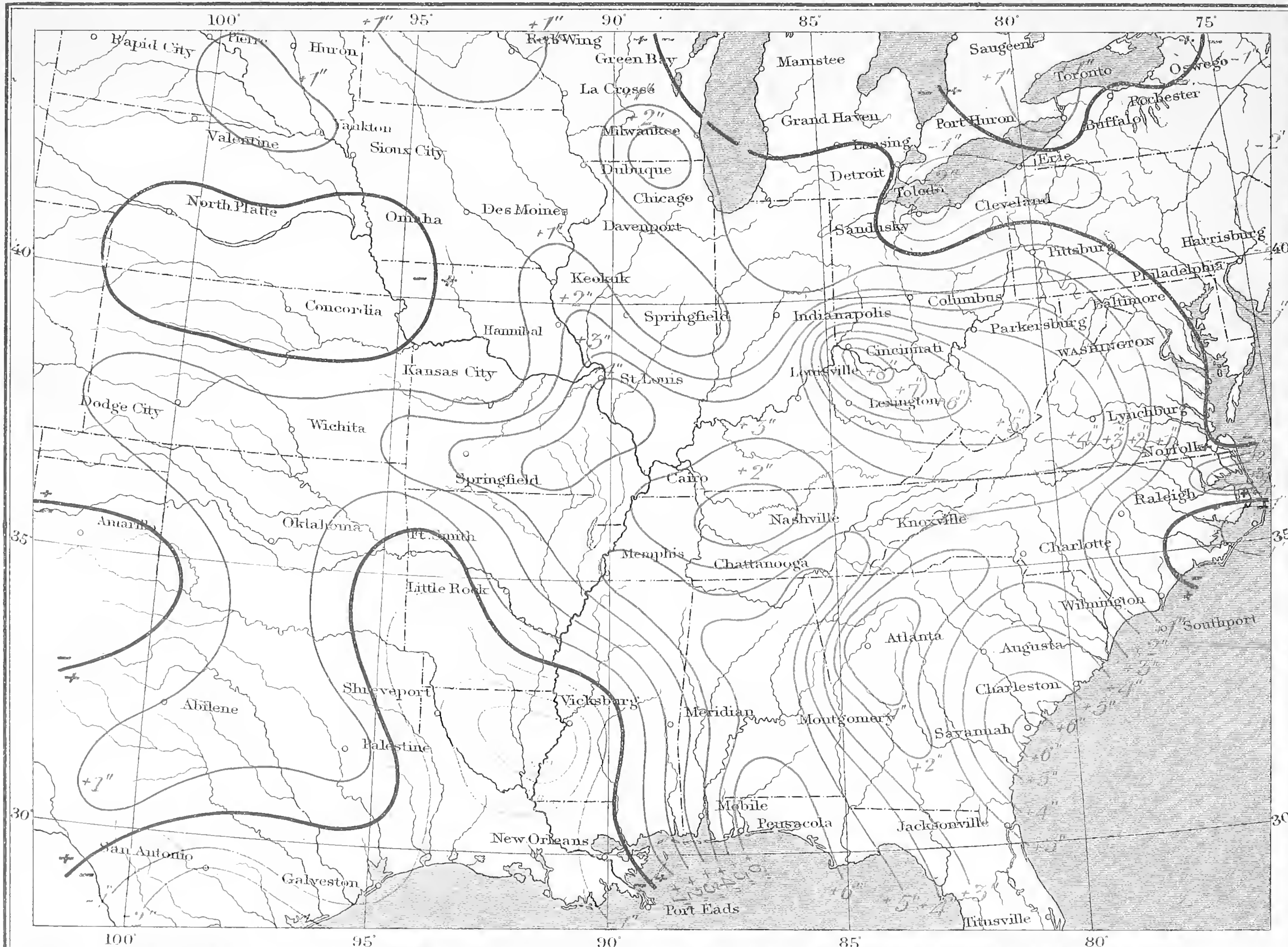


Pl. LVI.

DEPARTURE FROM NORMAL PRECIPITATION, MARCH, 1897.



DEPARTURE FROM NORMAL PRECIPITATION, FEBRUARY 1 TO MARCH 31, 1897.



Pl. LVIII.

HYDROGRAPHS FOR FLOOD OF 1897.